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Abstract

The 2004 EU enlargement has triggered large and rapid migration movements from the new to the old member states. The scale of this outflow was unprecedented in the CEE history and its structure was also different from previous emigration waves as it was more heavily biased towards young and educated people. I exploit this post-accession emigration wave to study the aggregate and redistributive effects of emigration. Using a two–country general equilibrium model with heterogeneous agents and endogenous migration choice calibrated to Polish data, I show that emigration lowers output per capita and improves the international investment position of the source country. Changes in population structure resulting from population outflows affect the wage distribution between high-skilled and low-skilled workers, thereby increasing economic inequalities. Moreover, I find that lifting labour mobility barriers is beneficial not only for people who move abroad, but also for skilled never-migrants.

Keywords: migration, sending country, heterogeneous agents, EU accession

JEL classification: F22, J61, D31, D58

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1 Introduction

After joining the European Union (EU) in May 2004, Poland and other Central and Eastern European new member states (EU8[1]) have experienced significant migration outflows to the old member states that opened their labour markets for the new entrants[2]. Figure 1(a) clearly shows that the stock of emigrants from EU8 rose rapidly in the post-accession period. As reported by Baas et al. (2010), the migrant population from EU8 more than doubled between 2003 and 2007. This scale of outflow has never been observed before in the post-war history of Central and Eastern European (CEE) countries.

Interestingly, the EU enlargement changed not only the scale but also the structure of emigration from CEE countries: migrants became younger and better educated. Increasing emigration rates (defined as the shares of the native population of the given country residing abroad) of individuals holding the tertiary degrees and falling fractions of older individuals (65+) in emigrants population are clearly seen in Figures 1(b) - 1(d) and highlight the selective nature of these recent migration movements in terms of age and educational attainment. According to the calculations by Arslan et al. (2015) based on DIOC (Database on Immigrants in OECD and non-OECD Countries), the biggest difference between total and high-skilled emigration rates in 2010 was observed in Poland. The population of emigrants from this country was also characterized by the lowest share of older individuals. The selectivity of post-enlargement emigration from Poland in terms of age and education was also confirmed by a number of empirical studies (see, e.g. Fihel et al., 2006; Kaczmarczyk and Okólski, 2008; Kaczmarczyk et al., 2010; Barslund et al., 2014; Dustmann et al., 2015; White et al., 2018).

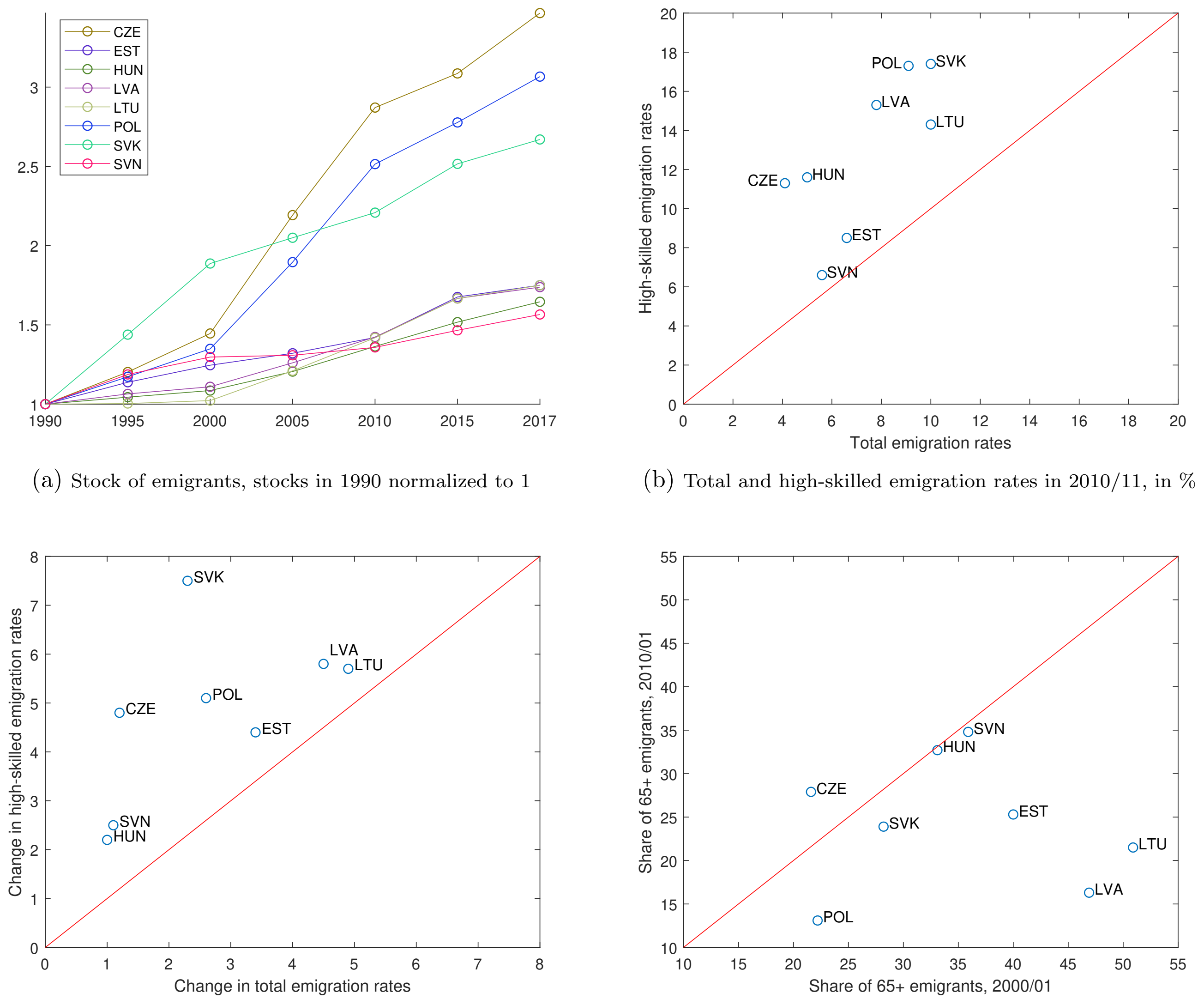
Post-accession migration dramatically affected labour markets in both host and sending countries and raised many concerns, especially in the context of demographics, long-term growth prospects, as well as inequality issues. Yet, we still know quite little about many potentially important effects of these recent migration flows on the sending economies, and much research is needed to fill this gap.

The empirical studies on source economies lack a general equilibrium dimension and therefore cannot assess all important macroeconomic effects, including welfare impact of outward migration movements. These empirical papers by construction have also little to say about

[1]Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia.

[2]The freedom of movement of workers is one of the four fundamental freedoms guaranteed by the EU regulations. EU nationals can not only freely travel to other member states but also take up employment. The first old member states that opened their labour markets for the new entrants where Ireland, UK and Sweden. Other EU countries took advantage of so-called transition agreements, which postponed access to their labour markets. Two countries, Germany and Austria, decided to introduce the transitional period of 7 years, which was the maximum period allowed by the EU regulations.

Figure 1: Changes in the size and structure of emigration from EU8



(a) Stock of emigrants, stocks in 1990 normalized to 1

(b) Total and high-skilled emigration rates in 2010/11, in %

(c) Changes in emigration rates between 2000/01 and 2010/11, in pp.

(d) Share of older (65+) emigrants in all emigrants (15+), in %

Source: (a) United Nations, Department of Economic and Social Affairs. Population Division (2017). Trends in International Migrant Stock: The 2017 revision. (b)-(d) Calculations by Arslan et al. (2015) based on DIOC and Barro and Lee (2013).

Notes: Emigration rates are calculated for the population aged over 15 and reflect the shares of the native population of the given country residing abroad.

the long-term effects, which can be potentially very different from the effects observed just after lifting migration barriers. Moreover, the empirical investigation of effects of post-accession emigration is hindered by still relatively short period that has passed since the EU enlargement and the limited availability of data on emigration size and structure. As a result, many important questions can be addressed only using a theoretical framework. However, the existing structural models with labour mobility usually do not include all key dimensions of individual heterogeneity and hence cannot capture all potentially important redistribution effects of migration and its impact on economic inequality. In this paper, I present the model which overcomes these shortcomings.

More specifically, I construct a general equilibrium model with endogenous migration choice, heterogenous agents and endogenous wage premium triggered by the imperfect substitutability between high- and low-skilled labour in the aggregate production, and use it as a tool to assess the consequences of emigration from Poland following the EU enlargement. The studied economy consists of two countries differing in the aggregate productivity levels: a (richer) large receiving economy and a (poorer) source country modelled as a small open economy. Individuals in the model are finitely-lived and differ in terms of their age, skills, idiosyncratic productivity and how costly it is for each of them to change the country of their residence. The representative firms produce a homogeneous good using capital and labour. Capital moves freely between countries and labour is imperfectly mobile, i.e. individuals are allowed to change their location, but migration is costly. First, the individuals living in the foreign country suffer a utility cost which is introduced to the model to reflect the individual attachment to home location. Second, to capture the fact that the economic performance of immigrants tends to be lower than that of the natives (see, e.g. Büchel and Frick, 2005; Clark and Drinkwater, 2008), moving involves an individual productivity loss.

The two countries in my setup correspond to the biggest EU8 economy - Poland and to the rest of the EU. I extensively use both macro and microdata sets to calibrate the model, and ensure that it closely replicates the key features of those economies. In particular, similarly to Gourinchas and Parker (2002) or Krueger and Ludwig (2013), I allow for deterministic productivity life-cycle profiles which differ across educational groups. As in Kindermann and Krueger (2014) or Kolasa (2020), I introduce skill-dependent individual productivity processes. Additionally, my model features stochastic life span with survival probabilities depending on age and skill level (see, e.g. Fehr et al., 2013). In my setup, all the above characteristics are allowed to differ between the two economies to capture the region-specific features. According to my knowledge, this is the first study which uses a model with so many aspects of household heterogeneity to analyse the consequences of labour mobility for the sending country, and in particular to study the EU enlargement episode.

I use my model to simulate the effects of opening up of the borders. Despite relatively sparse parametrization, the model fits the data very well. Most importantly, it succeeds in replicating the key characteristics of post-accession emigration from Poland, including the bias in the worker outflows towards young and highly skilled individuals.

Allowing for labour mobility leads to a substantial outflow of workers from the poorer country. Assuming the current productivity differential between Poland and the rest of the

EU, in the long run more than 14% of agents born in Poland live abroad. Since emigration alters the size and composition of population in terms of age, education and individual labour productivity, it affects important macroeconomic variables. Indeed, the decrease in effective labour supply, accompanied by the outflow of capital, results in lower output per capita in the country of origin. Moreover, the rising share of elder agents boosts the supply of savings, thereby improving the net international investment position of the emigration country, which increases in the long run by 17.7% of output.

Outmigration shifts the skill composition of the population towards unskilled workers and raises the wage difference between skill groups, thereby pushing inequalities up. The effects of the higher wage differential are, however, mitigated by the disproportionately high outflow of individuals from the lower end of individual productivity distribution and by the declining share of skilled agents, since this skill group is more differentiated in terms of labour income. Therefore, the overall impact of emigration on inequalities is rather limited.

Lifting migration barriers allows agents to work in the richer economy and therefore improves their welfare. My simulations reveal that, after eliminating the effects of rising bequests, the gains of the emigration country are in the long run equivalent to around 0.45% of lifetime consumption. Obviously, all agents are not affected equally. Gains are the highest for skilled individuals born long after opening up the borders. The unskilled individuals who are close to finishing their working life at the moment of removing migration barriers and the unskilled never-migrants experience welfare losses.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the model. Section 4 discusses the model calibration. In section 5 I present the main findings. In doing so, I look both at the steady states and the transitional dynamics, and focus on the aggregates, inequalities and welfare. Section 6 concludes. The Appendices provide the formal definitions of the competitive equilibrium and the stationary equilibrium, describe the model solution algorithm, and extend the baseline model with remittances.

2 Related literature

Despite the great policy and economic relevance, the consequences of migration for the sending countries remain relatively underresearched (Clemens, 2011; Zaiceva, 2014). Migration economics has so far focused mostly on impacts of immigration, trying to explain how the movement of people affect the economic situation of countries that receive migrants (see i.e. Borjas (1994), Dustmann et al. (2016), Kerr and Kerr (2011) or Okkerse (2008) for extensive immigration literature surveys).

The empirical studies about sending countries, such as Mishra (2007), Hazans and Philips (2010) or Elsner (2013a), focus mainly on migrants' characteristics and impact of migration flows on the local labour markets. Papers investigating the effect of emigration from Poland after joining the EU (see e.g. Fihel et al., 2006; Kaczmarczyk and Okólski, 2008; Kaczmarczyk et al., 2010; Barslund et al., 2014; Dustmann et al., 2015; White et al., 2018) emphasise the selectivity of emigration that manifest itself in the bias towards highly educated people and point out that, although the overall impact of the increased population outflow on the Polish labour market was rather moderate, changes in the skill composition of non-migrants' population affected the wage distribution between workers with different educational backgrounds. Since the above papers use purely statistical or econometric tools and abstract from general equilibrium aspects, they cannot assess all important macroeconomic effects. Moreover, this kind of frameworks by construction have little to say about long-term effects which can be potentially very different from effects observed just after lifting migration barriers. My paper overcomes those problems by using a structural general equilibrium setup.

This study is also related to studies by Klein and Ventura (2009), Elsner (2013b), Marchiori et al. (2013), Aubry et al. (2016), Biavaschi et al. (2020) and Caliendo et al. (2020) which use structural models to assess the labour market, output and welfare effects of migration from the perspective of the sending countries. Klein and Ventura (2009) use a two-region life-cycle model with endogenous migration and cross-country TFP differences and find the large gains in output, capital accumulation, and welfare from removing barriers to labour mobility. Elsner (2013b) calibrates the structural model of labour demand using the data from Lithuania to find a significant effect of emigration on the wage distribution between young and old workers. Marchiori et al. (2013) develop a multi-region general equilibrium model of the world economy characterized by overlapping-generations dynamics and argue that prevalent high-skilled emigration and brain drain can be very harmful for the sending countries. Aubry et al. (2016) use a multi-country model that accounts for the interactions between the labour market, fiscal, and market size effects of migration and quantify the effects of global migration on the welfare of non-migrant OECD citizens. Biavaschi et al. (2020) use a multi-country model with trade, remittances and human capital externalities to compare the current world with a counterfactual where the skill structure of migrants is changed, i.e. all migrants are neutrally selected from their home countries, and find that migration is beneficial for most receiving economies and for the sending economies where migration externalities such as remittances, brain gain and network effect in trade are strong. Caliendo et al. (2020) construct a multi-country dynamic general equilibrium model with heterogenous households and firms to study effects of changes in trade and migration policies following the 2004 EU enlargement. They find that high-skilled households from the new member state countries are the largest winners of the EU integration. My paper differ from those studies by including all important dimensions of household heterogeneity. More specifically, neither of the above papers use the model with life-cycle features and uninsurable individual risk and hence cannot evaluate the impact of workers' movement on economic inequality.

Technically, my model is closely related to the setup developed by Lee (2018). Yet, in contrast to my paper, Lee (2018) looks at the migration from the perspective of a recipient country and studies the consequences of doubling the H-1B visa quota for the skilled immigration to the US. To my knowledge, my paper is the first study using this kind of framework to investigate the consequences of migration for the country of origin.

3 The model

The model economy consists of two countries: an infinitely small home country H and a large foreign economy F. Each country is populated by heterogeneous households and homogeneous goods producers. Countries differ in aggregate productivity levels which translate into different wage levels. This in turn creates the incentives for agents born in the country with lower wages (country H) to emigrate to the country with higher wages (country F).

I use upper case letters to denote the aggregates and lower case letters for variables expressed in per capita terms. Following the notation of Conesa et al. (2009), I use prime to denote next period's individual choice variables. The remaining variables are indexed with time subscript t.

3.1 Foreign economy

Workers

Agents appear in the economy at the age of 24 and are assigned age index $j = 1$. They can live up to 100 years ($j = J = 77$) and they are subject to age-, country- and skill-specific mortality risk. At each point in time t, the foreign economy is thus populated by 77 overlapping generations, and the size of generation j is denoted by $N^F_{j,t}$. The agents that die before the maximum age of J leave unintended bequests, which are distributed equally among all living individuals born in the country.

At the beginning of life cycle, individuals are exogenously assigned skill level s which can be either high or low, $s \in \mathcal{S} = \{h, l\}$, and which does not change throughout agents' lives. Agents are born with zero assets a and the level of their assets cannot be negative, $a \in \mathcal{A} = [0, \infty]$, i.e. they can be liquidity constrained. All individuals supply inelastic labour and their labour income is given by $w^{Fs}_t e^{Fs}_j z$, where w^{Fs}_t denotes the aggregate wage per unit of efficiency labour received by agents with skill level s working in country F, e_j^{Fs} denotes the deterministic component of labour productivity that depend on age and skill level, and z denotes idiosyncratic productivity shock which follows the first order Markov process with states $z \in \mathcal{Z} = \{z_1, z_2, ..., z_N\}$ and transition matrix $\pi(z'|z)$, $z, z' \in \mathcal{Z}$. My model assumes exogenous retirement upon reaching the age of 64 ($j = 41$), and therefore I set $e_j^{Fs} = 0$ for $j > 41$, $\forall s$.

Workers are expected utility maximizers, with preferences defined over consumption streams and the period utility function given by:

$$u(c) = log(c) \tag{1}$$

The decision problem of an agent can be defined as follows (for ease of notation, I skip the skill indices):

$$V_{j,t}^F(a, z) = \max_{c,a' \geq 0} \{u(c) - \beta^F \psi_j^F \sum_{z'} \pi(z'|z) V_{j+1,t+1}^F(a', z')\} \tag{2}$$

subject to:

$$c + a' = (1 + r_t)(a + b_t^F) + w_t^F e_j^F z \tag{3}$$

where β^F denotes the discount factor of agents born in the foreign country, ψ_j^F is a probability of surviving from period j to period $j + 1$, r_t is a world interest rate, and b_t^F denotes the accidental bequests received by agents living in the foreign economy.

Production

A representative competitive firm rents capital and hires labour, and uses them to produce output Y_t^F according to the two-level CES production function (Krusell et al., 2000):

$$Y_t^F = A^F F^F(K_t^F, H_t^F, L_t^F) = A^F \left(\alpha^F (L_t^F)^\gamma + (1 - \alpha^F) \left[\rho^F (K_t^F)^\eta + (1 - \rho^F)(H_t^F)^\eta\right]^{\frac{\gamma}{\eta}}\right)^{\frac{1}{\gamma}} \tag{4}$$

where A^F denotes the total factor productivity in the foreign economy, K_t^F is the aggregate capital used in the production process in the foreign country, and H_t^F and L_t^F denote the aggregate labour provided by, respectively, skilled and unskilled workers living in that country. Parameters γ and η determine the elasticities of substitution between the factors of production. Parameters α^F and ρ^F determine the factor shares.

The optimal factor prices satisfy the following first-order conditions:

$$
\begin{aligned}
r_t &= A^F F_K^F(K_t^F, H_t^F, L_t^F) - \delta^F \\
w_t^{Fh} &= A^F F_H^F(K_t^F, H_t^F, L_t^F) \\
w_t^{Fl} &= A^F F_L^F(K_t^F, H_t^F, L_t^F)
\end{aligned}
\tag{5}
$$

where δ^F denotes the capital depreciation rate and F_x^F is the partial derivative of function F^F with respect to x.

Demography

The demographic processes in the foreign country are determined by changes in the size of the youngest generation $N_{1,t}^F$ and survival probabilities ψ_j^{Fs}, which are both assumed to be exogenous. Although the foreign country receives migrants, the immigrant population does not affect the demographic situation of the economy as the (sending) country H is infinitely small compared to the foreign economy.

The total number of living agents N_t^F is given by:

$$
N_t^F = \sum_{j=1}^{J} N_{j,t}^F = \sum_{s\in\{h,l\}} \sum_{j=1}^{J} N_{j,t}^{Fs} \tag{6}
$$

where $N_{j,t}^F$ denotes the number of agents aged j and $N_{j,t}^{Fs}$ is the number of agents aged j with skills s.

The growth of population of country F can be written as follows:

$$
n_{t+1}^F = \frac{N_{t+1}^F}{N_t^F} - 1 \tag{7}
$$

and the number of agents in each generation evolves according to:

$$
N_{j+1,t+1}^F = \sum_{s\in\{h,l\}} \psi_j^{Fs} N_{j,t}^{Fs} \tag{8}
$$

I allow population growth to differ from zero. Thus, the number of individuals in each cohort becomes nonstationary and it is convenient to express the size of cohorts relative to the size of the youngest generation:

$$
N_{j,t}^{F,rel} = \frac{N_{j,t}^F}{N_{1,t}^F} \qquad N_{j,t}^{Fs,rel} = \frac{N_{j,t}^{Fs}}{N_{1,t}^F} \tag{9}
$$

and define the growth rate of the youngest cohort $n_{1,t+1}^F$:

$$
n_{1,t+1}^F = \frac{N_{1,t+1}^F}{N_{1,t}^F} - 1 \tag{10}
$$

This allows us to express equations 6 - 8 in relative terms in the following way:

$$N_t^{F,rel} = \sum_{s\in\{h,l\}} \sum_{j=1}^{J} N_{j,t}^{Fs,rel} \tag{11}$$

$$n_{t+1}^F = \frac{N_{t+1}^{F,rel}}{N_t^{F,rel}}(1 + n_{1,t+1}^F) - 1 \tag{12}$$

$$N_{j+1,t+1}^{F,rel} = \sum_{s\in\{h,l\}} \frac{\psi_j^{Fs} N_{j,t}^{Fs,rel}}{1 + n_{1,t+1}^F} \tag{13}$$

3.2 Home country

Workers

The population structure in the home country is similar to that of the foreign economy. Thus, the country is populated by J overlapping generations of individuals differing in their skill levels and idiosyncratic productivity.

The crucial difference between both economies is that the individuals born in the home economy are allowed to switch the country of their residence[3]. In the model I consider only permanent relocations, i.e. there are no return migrations. This assumption is common in the migration literature, see, e.g. Klein and Ventura (2009), as it greatly simplifies the model solution. Moreover, there is no reliable data on return migrants which would make it difficult to calibrate the model[4].

Although migration is possible, it comes at a cost: emigrants suffer from the random utility flow cost λ. Letting λ be stochastic allows to reflect the differences in individuals' willingness to live abroad. As shown in Kennan and Walker (2011) and Kennan (2016), the attachment to home location is evident in the data and is an important determinant of individual migration decisions.

At the beginning of period, agents living in their country of birth, observe their individual utility flow cost λ which they will incur in each period of living abroad, and then decide whether they want to change the country of their residence. This cost can be thought of as the psychic cost of migration, which is widely known in the migration literature since Sjaastad (1962).

[3]In fact, I could also allow individuals from the foreign country to make migration decisions but, under my calibration, they would never decide to relocate as aggregate productivity and hence wages are much lower in the home country.

[4]As argued by Janicka and Kaczmarczyk (2016), the impact of return migration on the Polish economy has been rather limited since there is an increasing tendency towards more long-term migration and a growing orientation towards settlement.

The potential relocation to the foreign country takes place in the same period in which the emigration decision is made. If the agent decides to stay in his country of birth, in the next period he draws the utility flow cost which, for tractability, is independent of the cost he observed in previous periods of his life. Once the location choice is realized, agents decide about their desired consumption c and next period's assets level a'.

Since the utility cost λ varies across people, two individuals with the same characteristics (same age, skill, productivity and assets level) can differ in their relocation decision. For convenience, let's define the threshold $\lambda^s_{j,t}(a,z)$, such that the individuals aged j with skill level s, assets a and productivity z decide to emigrate from the home country in the current period if their utility cost of migration λ satisfies $\lambda < \lambda^s_{j,t}(a,z)$ and decide to stay in the home country otherwise.

The migration decision problem of an agent born in the home economy who starts the period in his birth country can be expressed as follows (again, for ease of notation, I skip the skill indices):

$$V^H_{j,t}(a,z,\lambda) = \max_{m\in\{0,1\}} \{m v^{migr}_{j,t}(a, z^F_{min}, \lambda) + (1-m) v^{stay}_{j,t}(a,z)\} \tag{14}$$

where $v^{migr}_{j,t}(a,z,\lambda)$ denotes the value function if the agent decides to emigrate in the current period ($m=1$) and $v^{stay}_{j,t}(a,z)$ denotes the value function if he decides to stay in his home country ($m=0$). To capture the fact that the economic performance of immigrants tends to be lower than that of the natives (see, e.g. Hendricks, 2001; Büchel and Frick, 2005; Clark and Drinkwater, 2008), I assume that the stochastic productivity component of new emigrants, i.e. in the first period of emigration, always, i.e. with probability equal to 1, takes the lowest value observed in the destination country z^F_{min}.

The decision problem of an individual who chooses to relocate to the foreign country is given by:

$$v^{migr}_{j,t}(a,z,\lambda) = \max_{c,a'\geq 0} \{u(c) - \lambda + \beta^H \psi^F_j \sum_{z'} \pi(z'|z) v^{migr}_{j+1,t+1}(a',z',\lambda)\} \tag{15}$$

subject to:

$$c + a' = (1+r_t)(a + b^H_t) + w^F_t e^F_j z \tag{16}$$

where $u(c)$ is given by 1 and β^H denotes the discount factor of agents born in the home economy.

As the discount factor measures the subjective time preference of agents, I assume that it does not depend on the country of living, but rather on the country of birth. In other words, the migration decision does not change the rate which agents use to discount future utility flows.

The value of utility flow cost λ affects only individual's migration choice and, once the migration decision is made, has no impact on savings and consumption decisions. Consequently, it is possible to rewrite equation 15 as:

$$v^{migr}_{j,t}(a,z,\lambda) = \underbrace{\max_{c,a'\geq 0} \; \{u(c) + \beta^H \psi^F_j \sum_{z'} \pi(z'|z)\tilde{v}^{migr}_{j+1,t+1}(a',z')\}}_{\tilde{v}^{migr}_{j,t}(a,z)} - \lambda\Psi_j \tag{17}$$

where $\lambda\Psi_j$ is a sum of current and future discounted utility flow costs, with Ψ_j given by:

$$\Psi_j = \left[1 + \sum_{\tau=j}^{J-1}\left((\beta^H)^{\tau-j+1}\prod_{h=j}^{\tau}\psi^F_h\right)\right] \tag{18}$$

The decision problem of an agent who stays in the current period in his home country is given by:

$$\begin{aligned} v^{stay}_{j,t}(a,z) = \max_{c,a'\geq 0} \; \Bigg\{ & u(c) + \beta^H \psi^H_j \sum_{z'} \pi(z'|z)\Bigg[\Big(1-\eta_{j+1,t+1}(a',z')\Big)v^{stay}_{j+1,t+1}(a',z') \\ & + \eta_{j+1,t+1}(a',z')\Big(\tilde{v}^{migr}_{j+1,t+1}(a',z^F_{min}) - \Psi_{j+1}\mathbb{E}(\lambda'|\lambda' < \lambda_{j+1,t+1}(a',z'))\Big)\Bigg]\Bigg\} \end{aligned} \tag{19}$$

subject to:

$$c + a' = (1+r_t)(a + b^H_t) + w^H_t e^H_j z \tag{20}$$

where $(1-\eta_{j,t}(a,z))$ is the probability that the agent with given characteristics does not decide to change the country of residence. Next period, the individual decides to relocate to the foreign country if he draws the migration utility cost λ' which is smaller than the threshold utility cost $\lambda_{j+1,t+1}(a',z')$. The expected value of this cost is thus given by $\mathbb{E}\Big(\lambda'|\lambda' < \lambda_{j+1,t+1}(a',z')\Big)$ per each period spent on emigration.

While making emigration decisions, agents compare the value of $v^{migr}_{j,t}(a,z^F_{min},\lambda)$ with $v^{stay}_{j,t}(a,z)$ and decide to move to the foreign country if $v^{migr}_{j,t}(a,z^F_{min},\lambda) > v^{stay}_{j,t}(a,z)$. Equivalently, we can say that the agent decides to emigrate if he draws a utility flow cost which satisfies $\lambda < [\tilde{v}^{migr}_{j,t}(a,z^F_{min}) - v^{stay}_{j,t}(a,z)]/\Psi_j$. This condition allows us to write the threshold $\lambda_{j,t}(a,z)$ as:

$$\lambda_{j,t}(a,z) = \frac{\tilde{v}^{migr}_{j,t}(a,z^F_{min}) - v^{stay}_{j,t}(a,z)}{\Psi_j} \tag{21}$$

and the fraction of people who decide to emigrate as:

$$\eta_{j,t}(a,z) = F(\lambda_{j,t}(a,z)) \tag{22}$$

where F denotes the cumulative distribution function of λ.

Production

The production process in the home economy is similar to the one in the foreign country. Thus, output is produced according to the following production function:

$$Y_t^H = A^H F^H(K_t^H, H_t^H, L_t^H) = A^h \left(\alpha^H (L_t^H)^\gamma + (1-\alpha^H)\left[\rho^H (K_t^H)^\eta + (1-\rho^H)(H_t^H)^\eta\right]^{\frac{\gamma}{\eta}}\right)^{\frac{1}{\gamma}} \tag{23}$$

Parameters γ and η determining the elasticities of substitution between the factors of production are assumed to be the same in both economies. Parameters α^H and ρ^H are allowed to be country-specific to capture capital shares and ratios of wage of skilled workers to wage of unskilled workers in both countries.

Aggregate wages per unit of efficiency labour are given by the first derivatives of the production function with respect to the high-skilled and low-skilled labour:

$$\begin{aligned} w_t^{Hh} &= A^H F_H^H(K_t^H, H_t^H, L_t^H) \\ w_t^{Hl} &= A^H F_L^H(K_t^H, H_t^H, L_t^H) \end{aligned} \tag{24}$$

In the model, capital moves costlessly across countries which implies the equality of interest rates. As the home economy is infinitely small compared to the foreign one, the global interest rate is fully determined abroad. Thus, the aggregate capital used in the production process in the domestic economy K_t^H adjusts to satisfy:

$$r_t = A^H F_K^H(K_t^H, H_t^H, L_t^H) - \delta^H \tag{25}$$

Demography

The evolution of demographic processes in the domestic economy is more complex than in the foreign one: it is governed not only by exogenous mortality risk but also by outward migration movements, which affect both current demographic situation of the country and future number of newly born agents. Thus, in contrast to the foreign economy, changes in the size of the youngest cohort $N_{1,t}^H$ in home country are not purely exogenous but depend on migration processes.

The total number of agents born in the domestic economy N_t^H is given by:

$$N_t^H = \sum_{j=1}^{J} N_{j,t}^H = \sum_{j=1}^{J}(N_{j,t}^{stay} + N_{j,t}^{migr}) = \sum_{s\in\{h,l\}} \sum_{j=1}^{J}(N_{j,t}^{stay,s} + N_{j,t}^{migr,s}) \tag{26}$$

where $N_{j,t}^{stay,s}$ and $N_{j,t}^{migr,s}$ denote the number of agents born in the home country and living in, respectively, their country of birth and foreign economy (emigrants). Both numbers are measured in the beginning of the period, i.e. before migration decisions are made.

The number of agents in each generation evolves according to:

$$N_{j+1,t+1}^H = \overbrace{(1-\eta_{j,t}) \sum_{s\in\{h,l\}} \psi_j^{Hs} N_{j,t}^{stay,s}}^{N_{j+1,t+1}^{stay}} + \overbrace{\underbrace{\sum_{s\in\{h,l\}} \psi_j^{Fs} N_{j,t}^{migr,s}}_{old \quad migrants} + \underbrace{\eta_{j,t} \sum_{s\in\{h,l\}} \psi_j^{Fs} N_{j,t}^{stay,s}}_{new \quad migrants}}^{N_{j+1,t+1}^{migr}} \tag{27}$$

where *new migrants* refer to agents who emigrated in period t, *old migrants* refer to individuals who emigrated in previous periods and $\eta_{j,t}$ denotes the fraction of agents aged j who decide to emigrate in period t.

Again, as we allow for non-zero population growth, it is useful to express the size of each generation relative to the number of newly born agents:

$$\begin{aligned} N_{j,t}^{H,rel} &= \frac{N_{j,t}^H}{N_{1,t}^H} \qquad N_{j,t}^{stay,rel} = \frac{N_{j,t}^{stay}}{N_{1,t}^H} \qquad N_{j,t}^{migr,rel} = \frac{N_{j,t}^{migr}}{N_{1,t}^H} \\ & \qquad N_{j,t}^{stay,s,rel} = \frac{N_{j,t}^{stay,s}}{N_{1,t}^H} \qquad N_{j,t}^{migr,s,rel} = \frac{N_{j,t}^{migr,s}}{N_{1,t}^H} \end{aligned} \tag{28}$$

In the home country, the growth rate of the youngest cohort $n_{1,t+1}^H = \frac{N_{1,t+1}^H}{N_{1,t}^H} - 1$ is determined endogenously and depends on age-specific fertility, mortality and migration rates. Let me first express the total number of agents aged $j = 1$ appearing in the economy in period t as:

$$N_{1,t}^H = \sum_{i=15}^{i=49} \sum_{s\in\{h,l\}} \left(f_{i-23} \frac{(1-\eta_{i,t-1}) N_{i,t-1}^{stay,s} \Omega_{-23,1}^s}{\Omega_{i-23,i}^s} \right) \tag{29}$$

where f_j denotes age-specific fertility rate and $\Omega_{h,k}^s$ is the probability that the individual aged $j = h$ will survive till age $j = k$, i.e.:

$$\Omega_{h,k}^s = \prod_{j=h}^{k-1} \psi_j^{Hs} \tag{30}$$

In formula 29, I make two assumptions. First, agents bear children when they are between

15 (j=-8) and 49 (j=26) years old. Second, when the parent emigrates to the foreign country, he takes with him all his children who are younger than 24 years old. When agents appear in the model, i.e. reach age equal to 24, they start making their own migration decisions.

According to equation 29, the number of agents appearing in the model economy in period t depends on the number of fertile agents living in period $t-24$ who did not decide to relocate to foreign country between periods $t-24$ and $t-1$. These agents were between 15 (j=-8) and 49 (j=26) years old in period $t-24$ and between 38 (j=15) and 72 (j=49) years old in period $t-1$. To account for the fact that part of the individuals bearing children in $t-24$ could die before period $t-1$, I divide the number $(1-\eta_{i,t-1})N^{stay,s}_{i,t-1}$ by the survival probability $\Omega^s_{i-23,i}$. Finally, the number thus obtained is multiplied firstly by respective fertility rates and then by the probability of surviving from birth ($j=-23$) till age 24 ($j=1$) $\Omega^s_{-23,1}$. The latter multiplication is made to take into account that not all agents born in period $t-24$ survive till period t.

Dividing both sides of equation 29 by $N^H_{1,t-1}$, gives us the formula for the growth rate of the youngest cohort $n^H_{1,t}$:

$$1+n^H_{1,t}=\sum_{i=15}^{i=49}\sum_{s\in\{h,l\}}\left(f_{i-23}\frac{(1-\eta_{i,t-1})N^{stay,s,rel}_{i,t-1}\Omega^s_{-23,1}}{\Omega^s_{i-23,i}}\right) \tag{31}$$

3.3 Equilibrium conditions

An equilibrium path of the economy has to solve agent decision problems, reflect competitive factor prices and balance aggregate inheritances with unintended bequests. Moreover, the capital, labour and goods markets need to clear. The formal definitions of the competitive equilibrium and the stationary equilibrium are provided in Appendix A. The detailed solution algorithms used to solve the stationary equilibrium and the transition path are presented in Appendix B.

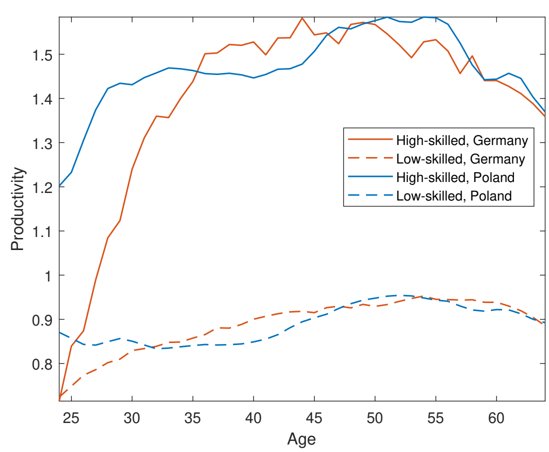
4 Calibration

Since this study analyses the consequences of emigration from Poland after Poland's entry to the EU, I calibrate the model such that country H represents Poland and country F represents the EU. I first calibrate the non-migration stationary equilibrium, in which agents are not allowed to relocate. Next, I move to the migration equilibrium and calibrate the utility costs of migration λ. As the skill structure of emigration is calibrated based on the data from Poland's Population Survey from 2011, for consistency's sake, most of the parameters describing demographics are as well calibrated using the data from that year.

Demographics, labour productivity and idiosyncratic risk
The share of skilled workers in country H ω^{Hh} is calibrated to 20.4%. This number matches the fraction of people with the university degree aged above 25 in the total number of people aged above 25 in Poland calculated using the data from Poland's Population Survey from 2011. The corresponding share in country F ω^{Fh} is calibrated to 23.3%, which, according to the Eurostat data, reflects the share of people with the university degree aged 25-74 in EU28 in the total number of people aged 25-74 in EU28 in 2011.

The deterministic age productivity profiles are assumed to be skill-specific and to differ between countries. For individuals living in Poland, these profiles e_j^{Hh} and e_j^{Hl} are calibrated based on the estimates of Kolasa (2017), which she obtained using Polish Household Budget Survey data. As the profiles for the whole EU are not readily available, for agents living in the foreign economy I use the German life cycle productivity profiles calculated by Fehr et al. (2013) and based on the data from German Socio-Economic Panel (SOEP)[5]. As Fehr et al. (2013) use more detailed classification of skills (1 - primary and lower secondary education, 2 - higher secondary education, 3 - tertiary education), I calculate the weighted average of profiles of the first and second skill category to obtain the productivity profile of low-skilled workers. I normalize the profiles such that the average productivity in the given country is equal to one and present them in Figure 2.

Figure 2: Life-cycle productivity profiles



Source: German profiles - Fehr et al. (2013), Polish profiles - Kolasa (2017).

The stochastic income component for an individual i is assumed to be skill- and country-specific. For each country $x \in \{H, F\}$, it is represented by the discretized Markov chain of a

[5]According to Poland's Population Survey from 2011, Germany was the second (after the UK) most popular destination among Polish emigrants. Around 22% of Poles living abroad in 2011 lived in Germany.

following continuous process:

$$
\begin{aligned}
\log z_{i,j}^{xs} &= \nu_{i,j}^{xs} + \epsilon_{i,j}^{xs} \\
\nu_{i,j}^{xs} &= \rho^{xs}\, \nu_{i,j-1}^{xs} + \vartheta_{i,j}^{xs} \\
\epsilon_{i,j}^{xs} \sim N(0, \sigma_{\epsilon xs}^2) \quad \vartheta_{i,j}^{xs} &\sim N(0, \sigma_{\vartheta xs}^2) \quad \epsilon_{i,j}^{xs} \perp \vartheta_{i,j}^{xs} \ \ i.i.d. \quad \nu_{i,0} = 0 \quad \mathbb{E}(\log z_{i,j}^{xs}) = 0
\end{aligned}
\tag{32}
$$

The parameters of the autoregressive part of the above process, i.e. ρ^{xs} and $\sigma_{\vartheta xs}^2$, are calibrated using estimates reported in Kolasa (2017) and Fehr et al. (2013). Variances of transitory income shocks are assumed to be equal in both skill groups, $\sigma_{\epsilon xs}^2 = \sigma_{\epsilon x}^2$, and are set to match Gini coefficients for working age population in Poland and Germany. For Poland, I target the value of 0.306, which corresponds to the Gini coefficient based on disposable income from 2011 as reported by OECD. The respective coefficient for Germany is equal to 0.298.

To approximate the distribution of the autoregressive part of individual productivity, I use a method presented in Tauchen and Hussey (1991) and assume three states. The transitory income shock is assumed to take two values, $-\sigma_{\epsilon x}$ and $\sigma_{\epsilon x}$, with equal probabilities. The distributions of labour productivity of newly born agents are calibrated to be the stationary distributions for the respective Markov chains.

The survival probabilities in Poland are calculated using Eurostat's data on life expectancy by age and educational attainment level in 2011. The survival probabilities by educational attainment are available neither for the whole EU, nor Germany. Therefore, to calculate the skill-specific probabilities of survival, I make a simplifying assumption that in Germany the difference between life expectancy of people with university degree and people without university degree is the same as in Poland. Using this assumption together with the data on average life expectancy and skill structure in Germany allows me to get the survival probabilities for different skill groups.

The Eurostat does not report life expectancy for the oldest cohorts. Therefore, to extend my series, I use the data from Human Mortality Database (HMD) (2018). As the HMD does not offer the survival probabilities by skill levels, I assume that the difference between life expectancy of people with university degree and people without university degree for the oldest cohorts is fixed and is the same as for the last cohort available in Eurostat. The thus obtained survival probabilities are next smoothed using fourth-order polynomials.

The growth rate of population in the foreign country n^F, which in stationary equilibrium is equal to the growth rate of the first cohort n_1^F, is set to -0.0035 and reflects the growth rate of the German population in 2011 reported by Eurostat. The fertility rates in the home country f_j are calibrated based on the Eurostat statistics for Poland from 2011. I assume that two agents are needed to form a new household and therefore divide Eurostat fertility rates by two. The implied population growth in the home economy in the non-migration stationary equilibrium is equal to -0.0147.

Preferences and technology

Parameters γ and η are calibrated to, respectively, 0.401 and -0.495, which is consistent with the estimates obtained by Krusell et al. (2000). The implied elasticity of substitution between capital and unskilled labour $\frac{1}{1-\gamma}$ is thus equal to 1.67 and the elasticity of substitution between capital and skilled labour $\frac{1}{1-\eta}$ equals to 0.67. The total factor productivity in the EU A^F is normalized to one.

The remaining nine model parameters, i.e. the discount factors β^F and β^H, capital depreciation rates δ^F and δ^H, total factor productivity in the home country A^H, and parameters in the production function which control the factor shares α^F, α^H, ρ^F and ρ^H are set to target the following nine data moments: the interest rate r, capital shares in both countries, ratio of output per capita in country F to output per capita in country H, investment to output ratios in both countries, ratios of wage of skilled workers to wage of unskilled workers in both countries and net foreign assets (NFA) to output ratio in the home economy. The values of calibrated parameters are presented in Table 1. Table 2 summarizes the calibration targets.

According to OECD data, the real long term interest rate averaged for the period 2004-2011 amounted to 1.63% in the EA19. I use this value as my calibration target for the world interest rate. For capital shares I use the standard value of 0.3.

The investment to output ratio in the foreign country is targeted at 21.2% and matches the ratio of gross fixed capital formation to GDP in the EU, averaged for 2004-2011 and calculated using Eurostat data. The respective share for Poland is equal to 19.9%. I use this value as my calibration target for the investment to output ratio in the home country.

As the gap in labour income of workers with different skill levels (skill premium) is already captured in the model by introducing skill-specific age productivity profiles, I set the ratios of wage per unit of efficiency labour of high-skilled and low-skilled workers to one. For the ratio of output per capita in both countries I use the value of 1.79, which corresponds to the ratio of purchasing power adjusted GDP per capita in the EU and in Poland, averaged for the period of 2004-2011 and calculated using Eurostat statistics.

The target value for the net foreign assets, defined in the model as the difference between the total assets held by the country's residents and the total capital used in the production process in this country[6], to output ratio in the home economy is set to -0.52, based on the

[6]The formulas used to calculate total assets held by the country's residents, the total capital used in the production process and the net foreign assets are provided in Appendix A (equations A.18, A.30 and A.29,

Table 1: Calibrated model parameters

	Parameter	Value
Discount factors	(β^H, β^F)	(0.961, 0.979)
Shares of skilled workers	$(\omega^{Hh}, \omega^{Fh})$	(0.204, 0.233)
Population growth rate in foreign economy	n^F	-0.004
Total factor productivity	(A^H, A^F)	(0.787, 1)
Production technology	(α^H, α^F)	(0.565, 0.612)
	(ρ^H, ρ^F)	(0.818, 0.852)
	(δ^H, δ^F)	(0.076, 0.0513)
	(γ, η)	(0.401, -0.495)
Income process of:		
High skill individuals	$(\rho_{Hh}, \sigma^2_{\epsilon Hh}, \sigma^2_{\vartheta Hh})$	(0.919, 0.018, 0.220)
	$(\rho_{Fh}, \sigma^2_{\epsilon Fh}, \sigma^2_{\vartheta Fh})$	(0.958, 0.035, 0.102)
Low skill individuals	$(\rho_{Hl}, \sigma^2_{\epsilon Hl}, \sigma^2_{\vartheta Hl})$	(0.822, 0.019, 0.220)
	$(\rho_{Fl}, \sigma^2_{\epsilon Fl}, \sigma^2_{\vartheta Fl})$	(0.956, 0.026, 0.102)
Migration costs	(μ_h, μ_l)	(3.435, 9.500)

Polish data from the period 2004-2011 reported by Narodowy Bank Polski and Eurostat.

Migraton costs

The characteristics of distributions of utility costs of migration λ are calibrated in such a way that the migration stationary equilibrium reproduces the size and skill structure of post-accession emigration from Poland.

To determine the size of emigration flows from Poland I use the data published by the Polish Central Statistical Office and calculate the annual differences in stock of Poles living abroad for more than 3 months. Using the stock differences rather than directly the data on population outflows seems to be more reasonable as my model does not allow for return migration and hence outflow of agents matches exactly the changes in stock of agents living abroad.

To calculate the annual differences in emigrant stock, I use the data from 2011-2016. I exclude the period just after Poland's accession as the massive population outflow in this period, see Figure 3, had rather transitory character and it is not reasonable to assume that such magnitude of flows can be observed in the long run. I also do not consider the time of the global financial crisis as fall in the emigrant stock in this period might result from cyclical

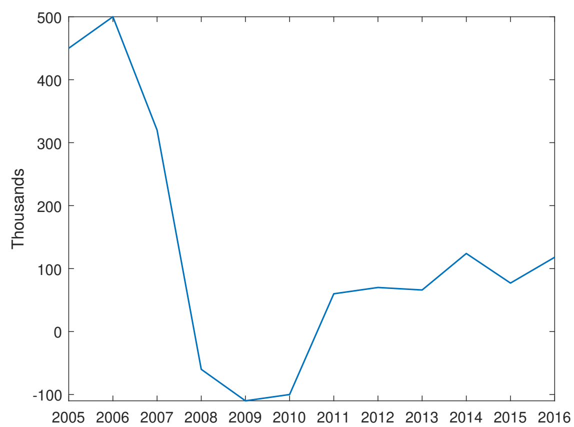
respectively).

Table 2: Target moments

	Target	Model	Source
Non-migration equilibrium			
Interest rate	0.0163	0.0163	OECD, 2004-2011
Investment share in output, country F	0.212	0.212	Eurostat, 2004-2011
Investment share in output, country H	0.199	0.199	Eurostat, 2004-2011
Capital share, country F	0.3	0.300	standard value
Capital share, country H	0.3	0.300	standard value
w^{Fh}/w^{Fl}	1	1.000	normalization
w^{Hh}/w^{Hl}	1	1.000	normalization
Ratio of output per capita in both countries	1.794	1.794	Penn World Table, 2004-2011
Net foreign assets to output ratio, country H	-0.523	-0.523	NBP and Eurostat, 2004-2011
Gini coefficient, labour income, country F	0.298	0.298	OECD, 2011
Gini coefficient, labour income, country H	0.306	0.306	OECD, 2011
Migration equilibrium			
Emigration flows to population ratio	0.002	0.002	Polish Central Statistical Office, 2011-2016
Share of skilled emigrants in total emigrant stock	0.251	0.252	Poland's Population Survey, 2011

factors which my model is silent about. After the period of financial crisis, the changes in the number of Poles living abroad stabilized and amounted to, on average, 86 thousands per year. Comparing this number with the size of Poland's population gives us the value of 0.0022 which I use as my calibration target.

Figure 3: Changes in stocks of Polish emigrants



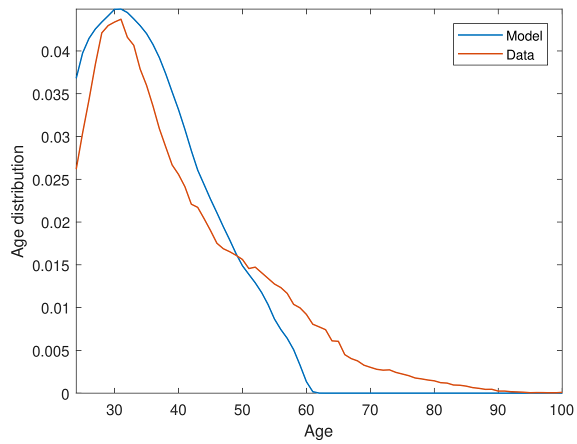
Source: Polish Central Statistical Office.
Notes: Data corresponds to the changes in number of Poles living abroad for more than two months (for 2004-2005) or more than three months (for 2006-2016).

For the share of skilled Polish migrants in the total number of Poles living abroad I target the value of 25.14%. This number corresponds to the share of Polish emigrants with the university degree aged above 25 in the total number of Polish emigrants aged above 25 as reported in the Poland's Population Survey from 2011.

For migration utility costs λ, I choose uniform distributions on the interval $[0, \mu_s]$, where ends of the intervals μ_s are skill-specific and set to $\mu_h = 3.45$ and $\mu_l = 9.5$. The uniform distribution is in this case very handy as the conditional expected values used in households' problem 19 can be then calculated analytically. As a robustness check, I follow Klein and Ventura (2009) and Kennan (2016) and replace the uniform distributions with the exponential distributions with skill-specific means. This modification yields very similar results and leads to the same conclusions as in the baseline calibration. The computation time is, however, much longer as the conditional expected values for exponential distribution need to be computed numerically[7].

[7] In order to calculate these conditional expected values of migration utility flow costs, I perform the numerical integration using global adaptive quadrature and default error tolerances implemented in MATLAB, see Shampine (2008).

Figure 4: Age structure of emigration flows



Source: Eurostat - age structure of migration flows from Poland averaged over the period 2009-2016.

Note that I do not directly target the age structure of migration. Hence, the comparison of structure implied by the model and the structure observed in the data can serve as a some sort of model validation. As shown in Figure 4, the model is rather successful in replicating the main features of age distribution of emigration flows from Poland. Consistently with the data, the model predicts that young people are much more willing to change the country of their residence. The emigration flows are the highest for the young cohorts and then they fall gradually. This is due to the fact that in the model economy agents reap the benefits of living abroad only during their working life, while they suffer the migration costs also during retirement. Hence, the older the agent is, the shorter the period of migration gains compared to the period migration utility losses is. Interestingly, my model is also able to capture the hump-shape of the migrants' age distribution which is observed in the data. As the emigration in my model economy results only from the differences in wages between countries, the model by construction generates no migration flows of agents after retirement. However, I do not consider it as a big shortcoming since actual migration of the retirees is also rather infrequent.

5 Results

This section discusses the main findings from the baseline model. I start with comparing the stationary equilibrium with no migration flows with migration stationary equilibrium. In doing so, I focus on the changes in the aggregate variables, inequalities and welfare. Next, I move to the analysis of transitional dynamics. This allows me to identify the differences between short-term and long-term consequences of outward migration movements.

5.1 Comparison of stationary equilibria

The aggregates

Opening the borders triggers large migratory impetus. In the migration steady state around 14.75% of agents born in country H live abroad. Emigration affects not only the size but also the structure of population and hence leads to changes in the main macroeconomics aggregates, see Table 3.

It is clear from Table 3 that emigration accelerates population decline. Although the fertility rates in the migration stationary equilibrium are the same as in the non-migration one, the growth rate of the first generation drops from -1.47% to -2.01% due to the outflow of young, fertile agents. Figure 5 presents the shift in the population age structure. As we can see, emigration contributes to population ageing: distribution of country's H population shifts towards older ages.

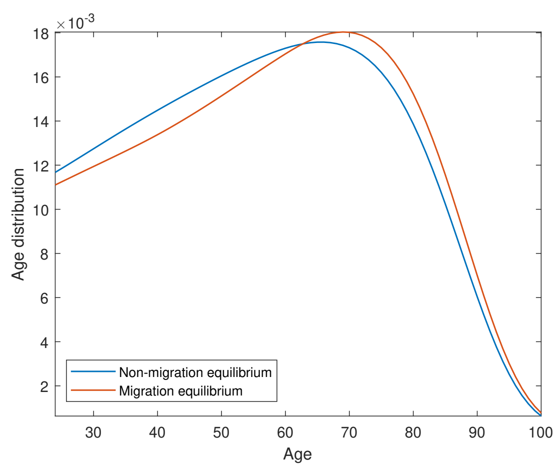
Table 3: Comparison of stationary equilibria

	Change
Ratio of emigrants to agents born in the country	14.75 p.p.
Growth rate of the first generation (n_1^H)	-0.54 p.p
Wage per efficiency unit of skilled labour (w^{Hh})	0.81%
Wage per efficiency unit of unskilled labour (w^{Hl})	-0.31%
Average labour income of skilled worker	3.03%
Average labour income of unskilled worker	0.13%
Capital stock per capita (k_h)	-4.90%
High skill labour per capita (h_H)	-5.41%
Low skill labour per capita (l_H)	-4.09%
Output per capita (y_H)	-4.60%
Capital stock per working age person	0.19%
High skill labour per working age person	-0.35%
Low skill labour per working age person	1.03%
Output per working age person	0.51%
NFA to output ratio	17.70 p.p.
Bequests (b_t^H)	7.13%

Notes: Table presents changes in migration equilibrium with respect to the non-migration equilibrium. All measures refer to the home country.

Since in the migration steady state both skilled and unskilled workers emigrate from country H, the supplies of both types of labour in this country decline. However, as the emigrants are relatively better educated than the stayers, the decrease in skilled labour is relatively stronger (5.41% vs 4.09% in per capita terms). This change in relative labour supplies clearly translates into change in relative wages. Under my calibration, the wage per efficiency unit of skilled labour in country H increases in the long run by 0.81%. For the unskilled workers, the fall of wage per efficiency unit of labour between two steady states is equal to 0.31%. The emigration leads therefore to the increase in the skill premium. This result is consistent with the findings presented by Dustmann et al. (2015), according to which emigration from Poland led to a slight increase in wages for high and medium skilled workers, i.e. workers with the highest outmigration rates. As shown by Dustmann et al. (2015), workers at the low end of the skill distribution might have experienced wage declines.

Figure 5: Population age structure

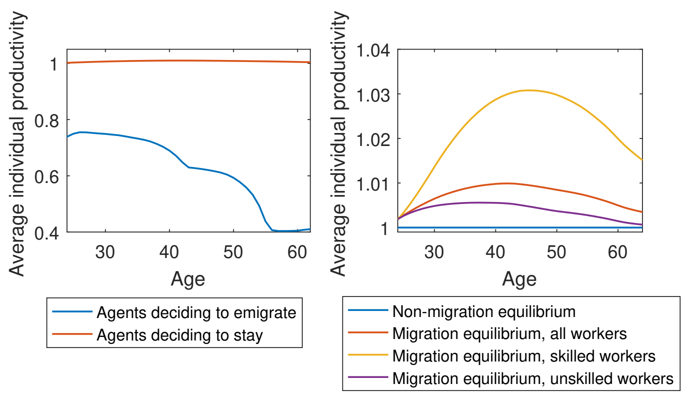


Even stronger changes can be observed when we look at the average labour income. For the workers with high skill level, the average labour income in the migration equilibrium is by more than 3% higher than in the equilibrium in which migration flows are not allowed. This increase, to a large extent, results from the selectivity of migration in terms of individual productivity. As can be observed in the left panel of Figure 6, agents with lower idiosyncratic productivities are in general more willing to emigrate to the foreign country: in every age cohort, the average idiosyncratic productivity of agents deciding to stay in the home country is higher than the average productivity of agents choosing to relocate to the foreign economy[8].

[8]The high-productivity individuals gain less due to emigration since the idiosyncratic productivity of all new migrants is assumed to take the lowest value observed in the destination country. Moreover, the increase in income brings more value to the low-productivity workers since their consumption levels are relatively low.

Thus, the average idiosyncratic productivity in country H rises, see the right panel of Figure 6. Although this selectivity pattern is more apparent for the group of skilled workers, it can be observed also among the unskilled agents. As a result, despite the decline in wage per efficiency unit of unskilled labour, the average labour income of unskilled workers in the migration steady state slightly increases (by 0.13%). The decrease in labour is accompanied

Figure 6: Age-profiles of average idiosyncratic productivity



Notes: Left figure depicts average individual productivities in the migration equilibrium calculated separately for agents from a given age cohort who decide to emigrate (new migrants) and agents who decide to stay in the home country. Right figure presents comparison of average individual productivities of country H residents in non-migration and migration equilibrium.

by the drop in capital (by 4.90% in per capita terms). The outflow of production factors leads in turn to the decline in output per capita (by 4.60%). These changes can be attributed to the already mentioned shift in the population age distribution and more specifically to the increase in the fraction of the oldest, unproductive agents. The retirees to working age population ratio in country H is much higher in the migration equilibrium (0.445 vs 0.354 in the initial non-migration steady state).

The crucial role of changes in population age structure for the behaviour of production factors and output per capita is confirmed when we look at the reaction of these variables expressed per working age person. The sign of reaction of capital, unskilled labour supply and output per working age person is reversed as compared to the reaction of their counterparts expressed in per capita terms. This result is easy to understand when we recall that average individual productivity of worker increases in the migration stationary equilibrium. However, in spite of this increase, we still observe the decline in high skill labour supply per working age person. This result comes from the changes in the population skill structure: the share of skilled agents drops in the migration steady state to 19.8% (vs 20.4% in the initial non-migration stationary equilibrium).

In the non-migration stationary equilibrium, the ratio of net foreign assets to output in country H amounts to -0.523. Changes in the population age structure in the migration equilibrium and more precisely the increase in the proportion of the elderly in the total population boost savings supply since older agents have on average higher assets holdings. In the closed economy setup, this increase would translate into lower interest rate. However, in the small open economy, like country H, the interest rate remains unchanged and the increase in savings results in the improvement of net international investment position (extra savings are invested abroad). Therefore, the NFA to output ratio in the home country rises significantly. In the long run, this proportion increases by 0.177 to -0.347.

Inequalities

Changes in the population structure can potentially affect the distributions of labour income and assets held by households and hence impact the inequalities in the economy. Table 4 presents different inequality measures which can be used to evaluate the impact of migration on income and assets disproportions.

Table 4: Inequality measures

	Non-migration equilibrium	Migration equilibrium
Gini coefficient, labour income	30.59	30.76
Gini coefficient, labour income, skilled workers	29.26	29.09
Gini coefficient, labour income, unskilled workers	28.04	28.01
Theil index, labour income:	14.85	15.05
Within (skill) group inequality	12.51	12.45
Between (skill) group inequality	2.34	2.60
Theil index, labour income, skilled workers	13.23	13.10
Theil index, labour income, unskilled workers	12.23	12.20
Hoover index, labour income	22.91	22.99
20:20 ratio, labour income	4.56	4.61
Gini coefficient, total disposable income	29.05	29.14
Gini coefficient, assets	54.70	54.85
Hoover index, assets	41.00	41.04

Notes: Measures referring to income are calculated for working age population residing in country H. Measures referring to assets are calculated for total population of the country.

According to all analysed indices, the effect of population outflow on labour income inequality is rather small[9]. The overall increase in the most popular inequality measure - the Gini coefficient (Gini, 1912) - amounts to only 0.17. This small change results from several driving forces. The main factor pushing the inequalities up is the rise in the wage differential between the skill groups. On the other hand, the increase in income inequalities is limited by the declining share of skilled agents in the economy. As clearly shown by labour income Gini coefficients calculated separately for both skill groups, the group of skilled workers is characterized by higher income inequalities. Moreover, the effects of the bigger wage difference between skilled and unskilled workers are also slightly offset by disproportionately high outflow of agents from the lower end of individual productivity distribution: the Gini coefficients calculated separately for both skill groups fall in the migration stationary equilibrium.

The same conclusion can be drawn from the analysis of changes in the Theil index (Theil, 1967). Contrary to the Gini coefficient, the Theil index allows to decompose inequalities into the part that is due to inequalities within the skill groups and the part that is due to differences between the skill groups. As we can see, the rise in between-group inequalities is partly mitigated by the drop in within-group inequalities. Altogether, these opposite driving forces result in small increase in total Theil index (from 14.85 to 15.05).

A slight increase in income disproportions is also visible when we look at the Hoover index (Hoover and Giarratani, 1999) and the 20:20 ratio which compares the income of the top 20% of population to the income of the bottom 20%. Initially, the labour income of the top 20% of country's H population is 4.56 times higher than the income of bottom 20%. In the migration stationary equilibrium, this measure increases to 4.61.

Bigger labour inequalities translate into slightly higher inequalities in the distribution of assets held by households. The assets Gini coefficient calculated for agents residing in the home country rises from 54.70 to 54.85. The Hoover index barely changes (increase from 41.00 to 41.04).

Welfare

In this section, I check whether migration is beneficial for the sending country and identify potential winners and losers of lifting migration barriers. To this end, I adopt the long run welfare measure used by i.a. Conesa et al. (2009), Fehr and Kindermann (2015) and Kindermann and Krueger (2014) that asks what is the percentage change in consumption that the agent born in the old steady state (without migration), under the Rawlsian veil of ignorance (that is, from an ex-ante perspective where neither the skill level nor any individual shock has been realized) would need to receive at all ages and all states of the world to be

[9]The studies on Poland document steady, but moderate rise in income inequalities in the post-accession period (see, e.g. Brzeziński et al., 2013, 2019). The quality of data on income distribution in Poland is, however, very poor, and hence, it is difficult to precisely estimate the inequality measures.

indifferent to being born in the new steady state (with migration).

Given the form of the utility function, the above measure, conditional on being born in country H, can be calculated as:

$$\Theta = 100 \left(exp \left(\frac{W(c_*) - W(c_0)}{\omega_1^{Hh}\Psi_1^h + \omega_1^{Hl}\Psi_1^l} \right) - 1 \right) \tag{33}$$

where c_0 is a consumption allocation in the non-migration steady state, c_* is the consumption allocation in the migration steady state, $W(c)$ is the ex-ante expected lifetime utility of agent born in country H, ω_1^{Hs} is the share of workers with skill level s in the cohort of newborn agents in country H and Ψ_1^s is defined in 18.

Opening up the borders creates welfare gains, equivalent to a 0.84% increase in consumption at all ages and all states of the world, see Table 5. Obviously, not all agents are affected equally. To check the consequences for different skill groups, I take the ex-post perspective (that is, after skill level has been realized) and disaggregate the welfare gains by agent skill type. Not surprisingly, the welfare gains for the group of skilled individuals are much higher, in excess of 1.78% of lifetime consumption. However, also unskilled agents benefit from opening the borders. Although emigration changes the education structure of the population and creates downward pressure on wage per unit of efficiency labour received by unskilled agents in the home economy, in the migration steady state the agents can potentially relocate to the richer country. This possibility, together with much higher bequests received by agents born in the sending country (see Table 3), more than offsets the negative effects of lower wages and creates the welfare gains equal to 0.62% of lifetime consumption.

Although all agents benefit from emigration opportunities, open borders might not necessarily be good for never-migrants, i.e. workers who never decide to emigrate. To quantify the effects for those individuals, I simulate the lifetime paths of individual productivity and mortality for 100 000 skilled and 100 000 unskilled workers. In each period of their lives, I assign them the utility costs of migration that are above their thresholds. In the next step, I calculate the consumption paths for those agents in the non-migration and in the migration stationary equilibrium. Note that while making the consumption-savings decisions in the migration steady state, agents take into account the possibility of future relocation, but in fact, due to high utility costs of emigration, they never change the place of their residence. I use these simulated consumption paths to calculate what percentage change in lifetime consumption the considered individual would require in the initial non-migration equilibrium in order to be as well of as in the migration equilibrium. I next calculate the simple averages of the thus obtained numbers, separately for both skill groups and report them in the last two rows of the first part of Table 5.

Table 5: Welfare effects: non-migration vs migration equilibrium

	Percentage change in lifetime consumption
All	0.84
Skilled	1.78
Unskilled	0.62
Skilled never-migrants	1.06
Unskilled never-migrants	0.11
Bequests fixed at the level from non-migration equilibrium	
All	0.45
Skilled	1.51
Unskilled	0.20
Skilled never-migrants	0.80
Unskilled never-migrants	-0.27

As could be expected, the welfare gains for the group of never-migrants are significantly lower than the gains of all agents. On average, the skilled agents would require 1.06% rise in lifetime consumption in the non-migration equilibrium in order to be indifferent to being born in the new steady state. For the unskilled individuals, the calculated measure amounts to 0.11%.

It should be noted that part of the gains of never-migrants result directly from the way in which the bequests are determined. In my model, I assume that all assets left by agents born in the country (that is, by both stayers and emigrants) who die unexpectedly before reaching the maximum age of J are summed up together and then distributed equally among all individuals born in this country. Since in the migration equilibrium part of the agents born in the home economy live in the richer foreign country and hence their assets are much higher than the assets of stayers, the received bequests rise significantly. This assumption is, however, a bit questionable as there is no high-quality data on how bequests are distributed in reality. Thus, one could make alternative, equally reasonable, assumptions on how the amount of inherited money is determined and end up with different conclusions about the welfare implications of emigration.

In order to get rid of this problem and eliminate the impact of bequests, I calculate the welfare effects between the non-migration equilibrium and the equilibrium which resembles the migration one with the only exception that the bequests received by agents born in the home country are set to their non-migration equilibrium level. Such welfare measures are reported in the second part of Table 5.

As we can see, the welfare gains calculated in this way are much lower than before. For the unskilled never-migrants, the welfare effects are negative and amount to -0.27% of lifetime consumption. Hence, although ex-ante all agents are better off in the migration equilibrium, after eliminating the impact of bequests, the unskilled never-migrants lose from open borders[10].

5.2 Transitional dynamics

The aggregates

Figures 7 depicts how the model variables behave along the transition path. In each figure, the first data point (transition period = 0) represents the value in the non-migration equilibrium. Transition period 1 represents the moment at which I permanently allow agents to change the country of their residence.

As we can see in the presented figures, most variables reach their migration equilibrium values in around 35 years after lifting barriers to labour mobility. In later periods, we observe only small, dying out, oscillations around the new steady state. The only variable which needs more time (around 70 years) to converge is the ratio of emigrants to total population of agents born in the home country.

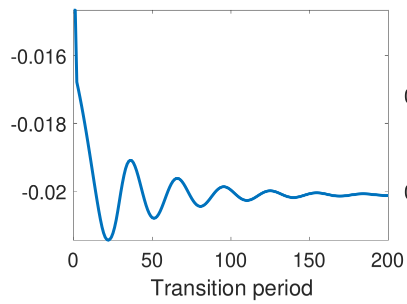
Oscillating behaviour of model variables results from the dynamics of the growth rate of the first cohort of agents born in the home country. This growth rate is determined in my model by the age-specific fertility rates (constant along the transition) and the age structure of population. The age structure changes after opening up the borders since different age cohorts are characterized by different propensities to emigrate. The growth rate of the first generation drops significantly in the second transition period[11], then it starts to oscillate in cycles which last around 24 years (time needed by newly born agents to appear in the model economy) and eventually die out when the age structure of population stabilizes.

Allowing for labour mobility induces immediately (transition period = 1) the outflow of around 0.25% of country's H population. In the following periods the outflow gradually declines and eventually stabilizes at the new steady state level equal to 0.22%. This pattern (immediate increase and later stabilization at the lower level), although not targeted in the calibration, qualitatively matches the observed population outflow from Poland after joining the EU. It is, however, fair to say that emigrant flows observed just after accession were much

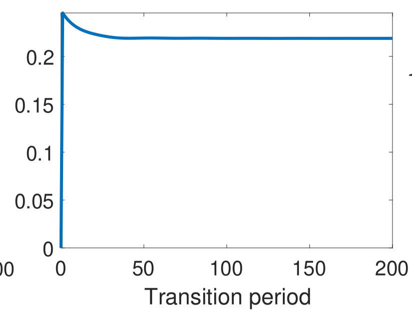
[10]The negative impact on welfare of unskilled agents can be limited by money transfers received from abroad. The Appendix C extends the baseline model with remittances and shows that in this scenario even the unskilled never-migrants benefit from open borders.

[11]Although agents are allowed to migrate already in the transition period=1, the growth rate in this period is the same as in the non-migration stationary equilibrium, as is depends on the population age structure from the previous period when the economy was still in the steady state, see equation 31.

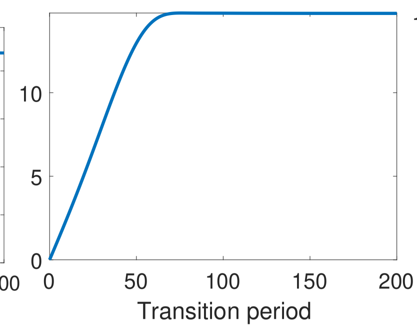
Figure 7: Macro variables along the transition



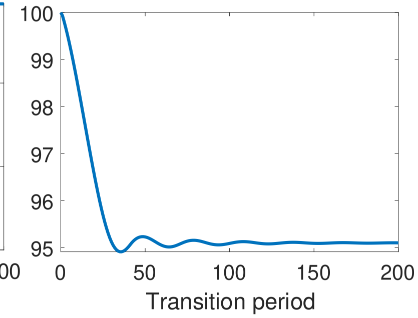
(a) Growth rate of the first cohort



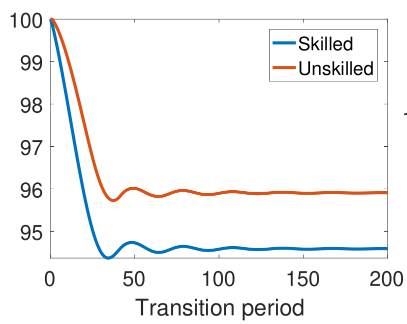
(b) Ratio of migration outflows to agents born in the country, in %



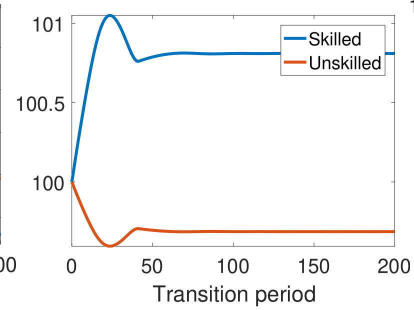
(c) Ratio of emigrants to agents born in the country



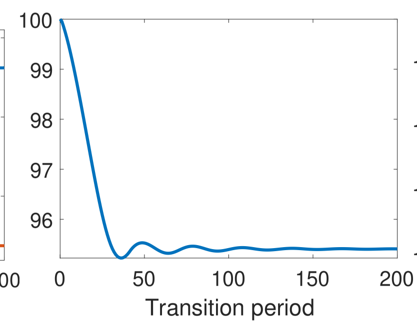
(d) Capital stock per capita



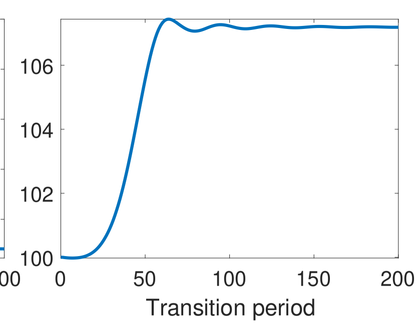
(e) Labour supplies per capita



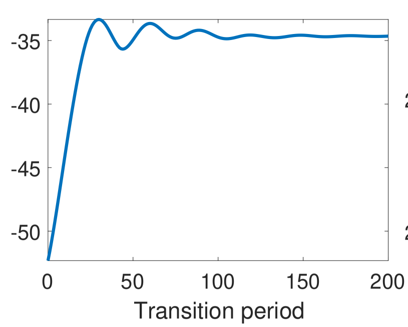
(f) Wage per unit of efficiency labour



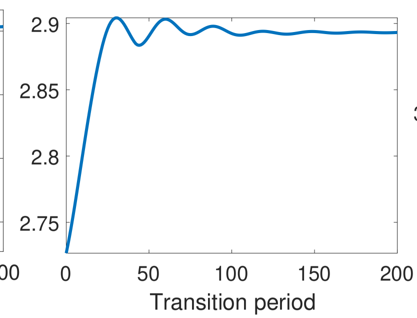
(g) Output per capita



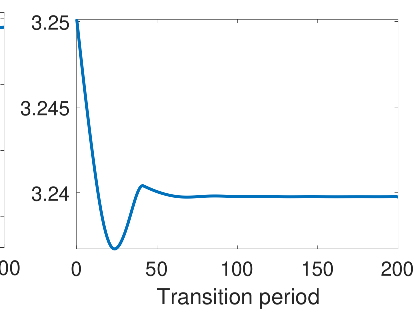
(h) Bequests



(i) NFA to output ratio, in %



(j) Assets to output ratio



(k) Capital stock to output ratio

Notes: Figures (d)-(h): values in the non-migration equilibrium normalized to 100.

bigger than those predicted by my model. The number of emigrants from country H increases monotonically along the transition path and ultimately reaches the new steady state level.

Lifting migration barriers leads immediately to outflow of all production factors. The fall in the supply of skilled labour is from the very beginning stronger than the decline in unskilled labour. As can be expected, these shifts in relative labour supplies translate into gradual increase (decrease) of wage per efficiency unit of skilled (unskilled) labour. The outflow of all production factors automatically lowers the production of the economy.

As discussed in section 5.1, the model predicts that outward migration improves the international investment position of the country. Interestingly, Figure 7 reveals that the increase in net foreign assets to output ratio results not only from the increase in total assets to output ratio but also from the drop in the ratio of capital stock to output. In other words, the investment rate of the economy falls and all additional savings due to population aging are invested abroad. The reason for lower capital to output ratio is the complementarity of capital and skilled labour assumed in our production function. Strong outflow of skilled workers entails smaller capital accumulation.

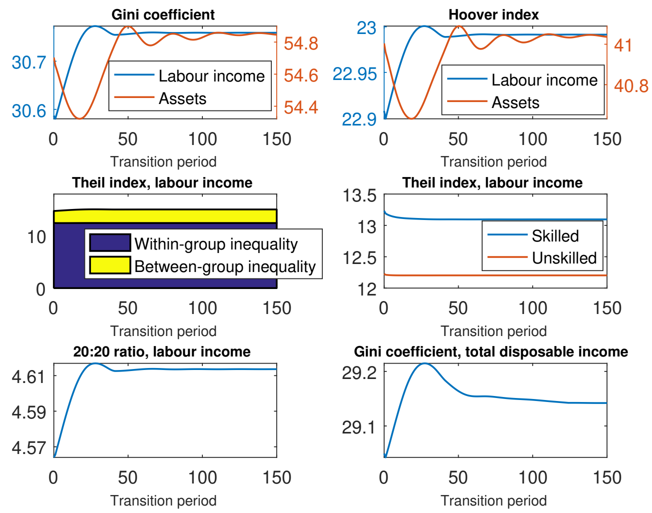
In the first years after lifting migration barriers, bequests received by agents born in the home country barely change. In that period, the number of emigrants living in richer foreign country is still quite small. Moreover, the age structure of emigrant stock closely resembles in that period the structure of migrant outflow: all migrants are relatively young and hence characterized by high survival probabilities. When outmigrants get older and their number gets bigger, we observe the gradual increase in unintended bequests left behind by the agents born in country H.

Inequalities

Figure 8 presents how different inequality measures behave along the transition. The conclusions about the impact of labour mobility on disproportions in labour income described in section 5.1 are valid also in the short run. Hence, we observe small increase both in Gini, Theil and Hoover indices and 20:20 ratio which are caused by the growing differences between wages of skilled and unskilled workers. The within-skill-group inequalities in labour income slightly decline.

Much more interesting dynamics is observed when it comes to assets inequalities. In the long run, there is a slight rise in Gini and Hoover indices for assets which is closely related to increasing income inequalities. Directly after opening up the borders, however, both measures decline. The trough levels of these measures coincides with the lowest values of the growth rate of the first cohort. Since the agents appear in the economy with zero assets, at this moment, in the economy there are relatively few young agents from the lower end of assets distribution.

Figure 8: Inequality measures along the transition



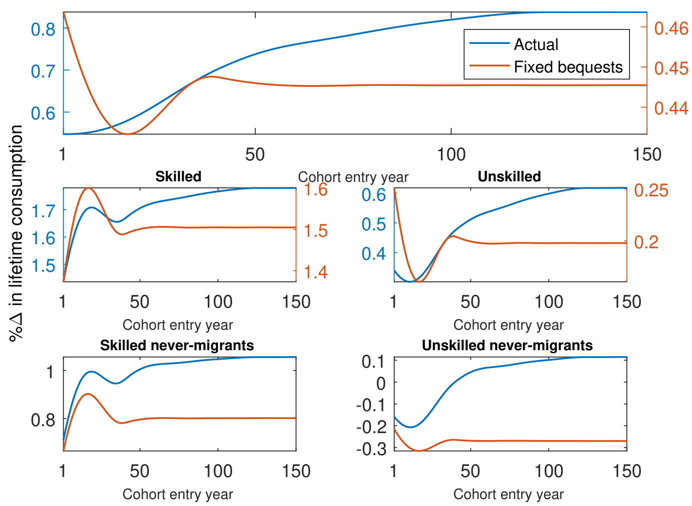
Welfare

I start the analysis of welfare with considering situation of the so-called future generations, i.e. the individuals that have not entered the economy before opening up the borders. For each cohort born during transition, I can calculate the measures analogical to measures calculated previously for the cohorts born in the new steady state.

As we can see in Figure 9, the overall gains are the lowest, in excess of 0.55% of lifetime consumption, for cohorts born just after opening up the borders and they increase gradually as the economy moves towards the new steady state. Disaggregation by household skill type shows that welfare effects are positive and increasing along the transition for agents with both skill levels. The increasing tendency for unskilled workers, observed despite declining wages of this skill group, point towards the dominant role of bequests in shaping welfare gains. Therefore, in the next step, I assume that bequests along the transition are constant and equal to their level from non-migration equilibrium and then calculate the respective welfare measures. Before doing that, however, I take a look at the situation of never-migrants, i.e. agents who face the utility cost of migration high enough to prevent them from leaving the country. As in the long-run equilibrium, the welfare effects for group of individuals who never emigrate turn out to be substantially lower than the effects calculated for all agents. Interestingly, the cohorts of unskilled workers born in the first 40 years after allowing for labour mobility are worse off than in the non-migration steady state. For these generations, the increase in the received bequests is thus not enough to offset the impact of lower wages.

As Figure 9 indicates, eliminating the impact of changes in bequests completely alters the dynamics of all welfare measures. The overall welfare effects display little variation along the transition path. However, the effects calculated separately for skilled and unskilled agents reveal considerable heterogeneity regarding their magnitude and evolution. For skilled workers gains are significantly larger and, in contrast to gains of unskilled individuals, they rise in the first years after lifting barriers to emigration. In later periods, they fall and then stabilize at a level which is a bit higher than in the first transition periods. The welfare gains of unskilled workers look like the mirror image of gains of skilled agents, i.e. the highest gains are enjoyed by generations appearing in the economy just after removing barriers to labour mobility. Obviously, considerably lower gains are enjoyed by the group of never-migrants. In fact, after eliminating the impact of bequests, it turns out that all future generation of unskilled never-migrants lose from open borders. The greatest loss, equal to -0.32% of lifetime consumption, is suffered by the generation born around 20 years after allowing for labour mobility.

Figure 9: Welfare effects, future generations

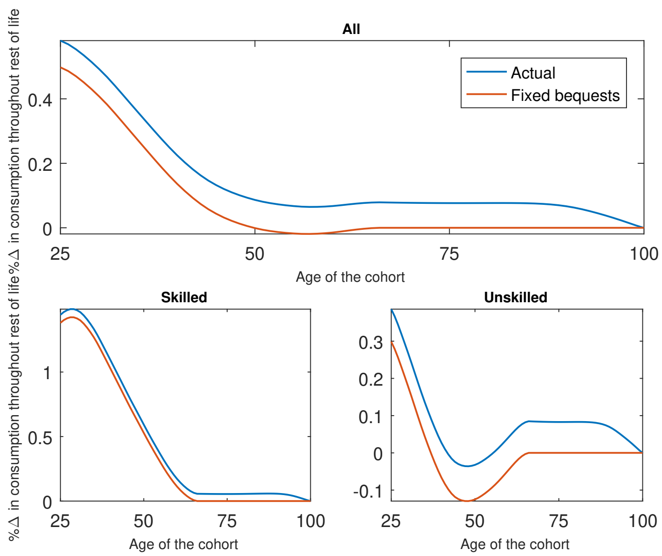


Notes: Fixed bequests: bequests along the transition are fixed at the level from non-migration equilibrium.

I next move to the situation of current generations, i.e. agents that are already alive in the non-migration equilibrium. As part of the lives of those individuals has already passed, I cannot use for them the concept of expected lifetime utility at birth which I used for generations born after removing migration barriers. Hence, for those cohorts I calculate what is the percentage change in consumption that the agent with given characteristics (defined by age, skills, assets, productivity and utility cost of migration) and living in the initial equilibrium would require throughout the rest of his life at all possible states of the world to be indifferent to living along the transition, and then take the simple averages of these conditional consumption changes by different age and skill groups.

Figure 10 presents average changes in consumption for different age cohorts of skilled and unskilled workers. The numbers on the horizontal axis represent the age of the cohort at the moment of opening the borders.

Figure 10: Welfare effects, current generations



Notes: Fixed bequests: bequests along the transition are fixed at the level from non-migration equilibrium.

As we can see in Figure 10, the welfare effects are rather heterogeneous across different age cohorts. Not surprisingly, individuals who are young at the moment of removing migration restrictions gain the most as they have more time in their life cycle to enjoy the benefits of open borders. On average, the smallest gains are experienced by agents who are close to finishing their working life and by the retirees. Those agents have very small (or, in case of retirees, even no) incentives to emigrate to the richer economy and their gains result mainly from changing situation in the home economy.

Interestingly, my simulations reveal that the gains of unskilled retirees are significantly higher than the gains of unskilled agents who are at the final stage of their professional career. It even turns out, that agents who are between 40 and 55 years old in the moment of migration reform suffer welfare losses. The consumption of this group of individuals drops due to lower earnings (fall in w^{Hl}) and the probability that they decide to emigrate to the richer foreign economy is for them relatively small. On the other hand, older agents enjoy welfare gains due to higher unintended bequests. As the level of consumption of those (old) agents is relatively low, even small unexpected increase in income received by those individuals leads to high percentage changes in consumption.

Again, I also calculate the welfare effects after eliminating the impact of changes in bequests. The curves are shifted downwards, i.e. the calculated welfare measures are lower, but the conclusions about the differences in welfare gains enjoyed by various age cohorts remain roughly the same. Obviously, the welfare effects for all cohorts of retirees are equal exactly to zero.

6 Conclusions

This paper looks at the short-term and long-term consequences of migration for the sending country. To this end, I develop a two–country general equilibrium model with endogenous migration choice and incomplete financial markets, and calibrate it to Polish data from the period following EU accession.

The constructed framework includes all important dimensions of household heterogeneity that are crucial to understanding the effects of migration, including idiosyncratic uncertainty, life-cycle features and differences in skills and willingness to live abroad. Despite relatively sparse parametrization, the model fits the data very well. Most importantly, it succeeds in replicating the key characteristics of post-accession emigration from Poland, including the bias in the worker outflows towards young and highly skilled individuals.

Thanks to the rich model structure, I could use it to analyse not only aggregate, but also redistributive consequences of migration. My analysis shows that removing migration restrictions leads to substantial changes in population structure. Firstly, there is a shift in age distribution towards older unproductive cohorts which leads to lower per capita supplies of production factors and lower output per capita. Since elder agents hold on average more assets, the international investment position of the sending economy improves. Secondly, outward migration shifts the skill composition of population towards unskilled workers and thus rises the wage differential between skill groups, leading to slight increase in income and assets inequalities. Lastly, since less productive individuals are more eager to change the country of their residence, we observe changes in distribution of individual productivity.

Opening up the borders gives to all agents the possibility of living and working in the richer region and hence is on average beneficial for the citizens of the sending country. My model implies that, after eliminating the effects of higher bequests, the gains of the emigration country are in the long run equivalent to around 0.45% of lifetime consumption. Welfare effects calculated separately for different household types display considerable heterogeneity regarding their magnitude and evolution along the transition. The gains are the highest for skilled workers born long after removing barriers to labour mobility. The welfare losses are experienced by the unskilled individuals who are in the final stage of their professional career at the moment of permanent reduction of migration costs. Moreover, my simulations reveal that also the unskilled individuals who in fact have never decided to emigrate lose from open borders.

This paper leaves a few doors open for further investigation. Firstly, to keep the model structure simple, my framework abstracts from the fiscal effects and the presence of a pension system. The outflow of young individuals can be, however, a great burden on the public purse and have serious consequences for the sustainability of the pension scheme. Secondly, faced with migration, countries may choose to implement policies aimed at limiting population outflow or fostering returns, such as decreasing the tax wedge for the young, or providing tax cuts and cash payments for migrants coming back home. An OLG framework with labour mobility, like the one developed in this paper, is a perfect tool for studying the efficacy of such policies. Thirdly, the increase in wages of skilled workers may encourage more human capital formation by those who stay and hence limit the detrimental effects of emigration on output. Studying the importance of this endogenous human capital channel is an interesting avenue for future research.

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Appendix

A Definition of competitive equilibrium

Foreign economy

Individual state variables are age j, skills s, assets a and individual labour productivity z. The aggregate state of the economy at time t is completely described by Φ_t^F, which is the joint measure of agents born in country F defined over age, skills, assets positions and individual labour productivity. Since I allow population growth to differ from zero, the number of individuals in each cohort is nonstationary. Hence, to make it stationary, I express the measure Φ_t^F relative to the size of the youngest generation.

Let $j \in \mathcal{J} = \{1, 2, ..., J\}$, $s \in \mathcal{S} = \{h, l\}$, $a \in \mathcal{A} = [0, \inf]$, $z \in \mathcal{Z} = \{z_1, z_2, ..., z_N\}$, and let $\mathbf{W} \in \mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z}$. Let $\mathbf{B}(\mathcal{A})$ be the Borel σ-algebra of $\mathcal{A}$ and $\mathbf{P}(\mathcal{J})$, $\mathbf{P}(\mathcal{S})$, $\mathbf{P}(\mathcal{Z})$ be the power sets of $\mathcal{J}$, $\mathcal{S}$, $\mathcal{Z}$, respectively. Let $\mathbf{M}$ be the set of all finite measures over the measurable space ($\mathbf{W}$, $\mathbf{P}(\mathcal{J}) \times \mathbf{P}(\mathcal{S}) \times \mathbf{B}(\mathcal{A}) \times \mathbf{P}(\mathcal{Z})$). To ease the notation, in the following I will use Φ_t^F instead of $\Phi_t^F(\mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z})$.

Definition 1 Given initial conditions b_1^F and Φ_1^F, a competitive equilibrium is a sequence of functions for the household $\{ V_t^F,\ c_t^F,\ a_t'^F\colon\ \mathbf{W} \rightarrow \mathbf{R}_+ \}_{t=1}^{\infty}$, production plans for the firm $\{k_t^F, h_t^F, l_t^F\}_{t=1}^{\infty}$, prices $\{r_t, w_t^{Fh}, w_t^{Fl}\}_{t=1}^{\infty}$, bequests $\{b_t^F\}_{t=1}^{\infty}$, and measures $\{\Phi_t^F\}_{t=1}^{\infty}$, with $\Phi_t^F \in \mathbf{M}$ such that:

1. given prices, bequests and initial conditions, for each t, V_t^F solves the functional equation (with c_t^F, $a_t'^F$ as associated policy functions):

$$V_t^F(j, s, a, z) = \max_{c, a' \geq 0} \{u(c) - \beta^F \psi_j^{Fs} \sum_{z'} \pi^{Fs}(z'|z) V_{t+1}^F(j+1, s, a', z')\} \tag{A.1}$$

   subject to:

$$c + a' = (1 + r_t)(a + b_t^F) + w_t^{Fs} e_j^{Fs} z \tag{A.2}$$

2. Prices r_t, w_t^{Fh}, w_t^{Fl} satisfy:

$$\begin{aligned} r_t &= A^F F_k^F(k_t^F, h_t^F, l_t^F) - \delta^F \\ w_t^{Fh} &= A^F F_h^F(k_t^F, h_t^F, l_t^F) \\ w_t^{Fl} &= A^F F_l^F(k_t^F, h_t^F, l_t^F) \end{aligned} \tag{A.3}$$

3. Bequests are given by:

$$b_t^F = \frac{\int (1-\psi_j^{Fs}) a'^{Fs}_{t-1}(j,s,a,z) d\Phi_{t-1}^F}{\int (1+n_{1,t}^F) d\Phi_t^F} \tag{A.4}$$

4. Markets clear:

$$k_t^F = \frac{\int a d\Phi_t^F}{\int d\Phi_t^F} + b_t^F \tag{A.5}$$

$$\begin{aligned} h_t^F &= \frac{\int e_j^{Fh} z d\Phi_t^F}{\int d\Phi_t^F} \\ l_t^F &= \frac{\int e_j^{Fl} z d\Phi_t^F}{\int d\Phi_t^F} \end{aligned} \tag{A.6}$$

$$A^F \left(\alpha^F (l_t^F)^\gamma + (1-\alpha^F) \left[\rho^F (k_t^F)^\eta + (1-\rho^F)(h_t^F)^\eta \right]^{\frac{\gamma}{\eta}} \right)^{\frac{1}{\gamma}} = c_t^F + i_t^F \tag{A.7}$$

where

$$c_t^F = \frac{\int c_t^F(j,s,a,z) d\Phi_t^F}{\int d\Phi_t^F} \tag{A.8}$$

and

$$i_t^F = k_{t+1}^F (1+n_{t+1}^F) - (1-\delta^F) k_t^F \tag{A.9}$$

5. Law of motion: For any subset $C = C_{\mathcal{J}} \times C_{\mathcal{S}} \times C_{\mathcal{A}} \times C_{\mathcal{Z}} \subseteq \{2, ..., J\} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z}$,

$$\Phi_{t+1}^F(C) = \frac{1}{1+n_{1,t+1}^F} \int \psi_j^{Fs} P_t^F \left((j,s,a,z), C \right) d\Phi_t^F \tag{A.10}$$

where

$$P_t^F \left((j,s,a,z), C \right) = \begin{cases} \pi^{Fs}(z'|z) & \text{if } (j+1, s, a_t'^F(j,a,s,z), z') \in C \\ 0 & \text{otherwise} \end{cases} \tag{A.11}$$

For any $C = C_{\mathcal{J}} \times C_{\mathcal{S}} \times C_{\mathcal{A}} \times C_{\mathcal{Z}} \subseteq \{1\} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z}$,

$$\Phi_{t+1}^F(C) = \begin{cases} \sum_{s \in C_{\mathcal{S}}} \sum_{z \in C_{\mathcal{Z}}} \nu_1^{Fsz} & \text{if } 0 \in C_{\mathcal{A}} \\ 0 & \text{otherwise} \end{cases} \tag{A.12}$$

where ν_1^{Fsz} is the share of workers with skill level s and labour productivity z in the cohort of newborn agents in country F.

Home economy

Individual state variables of agent born in the home country are age j, skills s, assets a, individual labour productivity z and migration cost λ. However, after relocating, the latter no longer affects agent's decisions. The aggregate state of the economy at time t is completely described by Φ_t^{stay} and Φ_t^{migr}, which are the joint measures of agents born in country H and residing in the beginning of period t, i.e. before migration decisions are made in, respectively, country H and country F, expressed relative to the size of the youngest living generation from country H. Φ_t^{stay} is defined over age, skills, assets positions, individual labour productivity and migration costs, and Φ_t^{migr} is defined over age, skills, assets positions and individual labour productivity.

Let $j \in \mathcal{J} = \{1, 2, ..., J\}$, $s \in \mathcal{S} = \{h, l\}$, $a \in \mathcal{A} = [0, \inf]$, $z \in \mathcal{Z} = \{z_1, z_2, ..., z_N\}$, $\lambda \in \Lambda = [0, \inf]$, and let $\mathbf{V} \in \mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z} \times \Lambda$ and $\mathbf{W} \in \mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z}$. Let $\mathbf{B}(\mathcal{A})$ and $\mathbf{B}(\Lambda)$ be the Borel σ-algebra of $\mathcal{A}$ and Λ, respectively, and $\mathbf{P}(\mathcal{J})$, $\mathbf{P}(\mathcal{S})$, $\mathbf{P}(\mathcal{Z})$ be the power sets of $\mathcal{J}$, $\mathcal{S}$, $\mathcal{Z}$, respectively. Let $\mathbf{K}$ be the set of all finite measures over the measurable space ($\mathbf{V}$, $\mathbf{P}(\mathcal{J}) \times \mathbf{P}(\mathcal{S}) \times \mathbf{B}(\mathcal{A}) \times \mathbf{P}(\mathcal{Z}) \times \mathbf{B}(\Lambda)$) and $\mathbf{M}$ be the set of all finite measures over the measurable space ($\mathbf{W}$, $\mathbf{P}(\mathcal{J}) \times \mathbf{P}(\mathcal{S}) \times \mathbf{B}(\mathcal{A}) \times \mathbf{P}(\mathcal{Z})$). For further convenience, I also define $\tilde{\Phi}_t^{stay}(\mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z}) = \int \Phi_t^{stay}(\mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z} \times \Lambda) d\lambda$. To ease the notation, in the following I will use Φ_t^{stay}, $\tilde{\Phi}_t^{stay}$ and Φ_t^{migr} instead of $\Phi_t^{stay}(\mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z} \times \Lambda)$, $\tilde{\Phi}_t^{stay}(\mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z})$ and $\Phi_t^{migr}(\mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z})$.

Definition 2 Given initial conditions b_1^H, Φ_1^{stay} and Φ_1^{migr} and a sequence of foreign prices $\{r_t, w_t^{Fh}, w_t^{Fl}\}_{t=1}^{\infty}$, a competitive equilibrium is a sequence of functions for the household $\{ V_t^H$, m_t: $\mathbf{V} \to \mathbf{R}_+ \}_{t=1}^{\infty}$, $\{ v_t^{stay}$, c_t^{stay}, $a_t'^{stay}$: $\mathbf{W} \to \mathbf{R}_+ \}_{t=1}^{\infty}$, $\{ \tilde{v}_t^{migr}$, c_t^{migr}, $a_t'^{migr}$: $\mathbf{W} \to \mathbf{R}_+ \}_{t=1}^{\infty}$, production plans for the firm $\{k_t^H, h_t^H, l_t^H\}_{t=1}^{\infty}$, prices $\{w_t^{Hh}, w_t^{Hl}\}_{t=1}^{\infty}$, bequests $\{b_t^H\}_{t=1}^{\infty}$, growth rates of the youngest generation born in the country $\{n_{1,t}^H\}_{t=1}^{\infty}$, growth rates of the population living in the country $\{n_t^H\}_{t=1}^{\infty}$, threshold migration costs $\{\lambda_{j,t}^s\}_{t=1}^{\infty}$, probabilities of emigrating $\{\eta_{j,t}^s\}_{t=1}^{\infty}$, and measures $\{\Phi_t^{stay}\}_{t=1}^{\infty}$ and $\{\Phi_t^{migr}\}_{t=1}^{\infty}$, with $\Phi_t^{stay} \in \mathbf{K}$ and $\Phi_t^{migr} \in \mathbf{M}$ such that:

1. given home and foreign prices, bequests and initial conditions, for each t:

   a) V_t^H solves the functional equation (with m_t as associated policy function):

$$V_t^H(j, s, a, z, \lambda) = \max_{m \in \{0,1\}} \{m(\tilde{v}_t^{migr}(j, s, a, z_{min}^{Fs}) - \lambda \Psi_j^s) + (1 - m) v_t^{stay}(j, s, a, z)\} \quad \text{(A.13)}$$

   b) v_t^{stay} solves the functional equation (with c_t^{stay}, $a_t'^{stay}$ as associated policy functions):

$$v_t^{stay}(j,s,a,z) =$$
$$= \max_{c,a'\geq 0} \Bigg\{ u(c) + \beta^H \psi_j^{Hs} \sum_{z'} \pi^{Hs}(z'|z) \Bigg[\Big(1 - \eta^s_{j+1,t+1}(a',z')\Big) v_{t+1}^{stay}(j+1,s,a',z')$$
$$+ \eta^s_{j+1,t+1}(a',z') \Big(\tilde{v}_{t+1}^{migr}(j+1,s,a',z^{Fs}_{min}) - \Psi_{j+1}\mathbb{E}(\lambda'|\lambda' < \lambda^s_{j+1,t+1}(a',z')) \Big) \Bigg] \Bigg\} \tag{A.14}$$

subject to:

$$c + a' = (1+r_t)(a + b_t^H) + w_t^{Hs} e_j^{Hs} z \tag{A.15}$$

c) $\tilde{v}_t^{migr}$ solves the functional equation (with c_t^{migr}, $a_t'^{migr}$ as associated policy functions):

$$\tilde{v}_t^{migr}(j,s,a,z) = \max_{c,a'\geq 0} \{u(c) + \beta^H \psi_j^{Fs} \sum_{z'} \pi^{Fs}(z'|z) \tilde{v}_{t+1}^{migr}(j+1,s,a',z')\} \tag{A.16}$$

subject to:

$$c + a' = (1+r_t)(a + b_t^H) + w_t^{Fs} e_j^{Fs} z \tag{A.17}$$

2. Marginal product of capital and wages w_t^{Hh} and w_t^{Hl} satisfy:

$$A^H F_k^F(k_t^H, h_t^H, l_t^H) = r_t + \delta^H \tag{A.18}$$

$$\begin{aligned} w_t^{Hh} &= A^H F_H^H(K_t^H, H_t^H, L_t^H) \\ w_t^{Hl} &= A^H F_L^H(K_t^H, H_t^H, L_t^H) \end{aligned} \tag{A.19}$$

3. Bequests are given by:

$$\begin{aligned} b_t^H = & \frac{\int (1-\psi_j^{Hs}) a_{t-1}'^{stay,s}(j,s,a,z)(1-\eta^s_{j,t-1}(a,z)) d\tilde{\Phi}_{t-1}^{stay}}{(1+n_{1,t}^H)(\int d\tilde{\Phi}_t^{stay} + \int d\Phi_t^{migr})} \\ & + \frac{\int (1-\psi_j^{Fs}) a_{t-1}'^{migr}(j,s,a,z^{Fs}_{min}) \eta^s_{j,t-1}(a,z) d\tilde{\Phi}_{t-1}^{stay}}{(1+n_{1,t}^H)(\int d\tilde{\Phi}_t^{stay} + \int d\Phi_t^{migr})} \\ & + \frac{\int (1-\psi_j^{Fs}) a_{t-1}'^{migr}(j,s,a,z) d\Phi_{t-1}^{migr}}{(1+n_{1,t}^H)(\int d\tilde{\Phi}_t^{stay} + \int d\Phi_t^{migr})} \end{aligned} \tag{A.20}$$

4. Growth rate of the youngest generation born in the country is given by:

$$n_{1,t}^H = \left(\int \frac{f_{j-23}(1-\eta^s_{j,t-1}(a,z))\Omega^s_{-23,1}}{\Omega^s_{j-23,j}} d\tilde{\Phi}_{t-1}^{stay} \right) - 1 \tag{A.21}$$

5. Growth rate of the population living in the country is given by:

$$n_t^H = \frac{(1+n_{1,t}^H)\int(1-\eta_{j,t}^s(a,z))d\tilde{\Phi}_t^{stay}}{\int(1-\eta_{j,t-1}^s(a,z))d\tilde{\Phi}_{t-1}^{stay}} - 1 \tag{A.22}$$

6. Threshold migration cost is given by:

$$\lambda_{j,t}^s(a,z) = \frac{\tilde{v}_t^{migr}(j,s,a,z_{min}^F) - v_t^{stay}(j,s,a,z)}{\Psi_j^s} \tag{A.23}$$

7. Probability of emigrating satisfies:

$$\eta_{j,t}^s(a,z) = F(\lambda_{j,t}^s(a,z)) \tag{A.24}$$

8. Markets clear:

$$\begin{aligned} h_t^H &= \frac{\int e_j^{Hh} z(1-\eta_{j,t}^h(a,z))d\tilde{\Phi}_t^{stay}}{\int(1-\eta_{j,t}^s(a,z))d\tilde{\Phi}_t^{stay}} \\ l_t^H &= \frac{\int e_j^{Hl} z(1-\eta_{j,t}^l(a,z))d\tilde{\Phi}_t^{stay}}{\int(1-\eta_{j,t}^s(a,z))d\tilde{\Phi}_t^{stay}} \end{aligned} \tag{A.25}$$

$$\begin{aligned} &A^h\left(\alpha^H(l_t^H)^\gamma + (1-\alpha^H)\left[\rho^H(k_t^H)^\eta + (1-\rho^H)(h_t^H)^\eta\right]^{\frac{\gamma}{\eta}}\right)^{\frac{1}{\gamma}} = \\ &= c_t^H + i_t^H + (1+n_{t+1}^H)nfa_{t+1} - (1+r_t)nfa_t \end{aligned} \tag{A.26}$$

where

$$c_t^H = \frac{\int c_t^{stay}(j,s,a,z)(1-\eta_{j,t}^s(a,z))d\tilde{\Phi}_t^{stay}}{\int(1-\eta_{j,t}^s(a,z))d\tilde{\Phi}_t^{stay}} \tag{A.27}$$

$$i_t^H = k_{t+1}^H(1+n_{t+1}^H) - (1-\delta^H)k_t^H \tag{A.28}$$

$$nfa_t = a_t^H - k_t^H \tag{A.29}$$

$$a_t^H = \frac{\int a(1-\eta_{j,t}^s(a,z))d\tilde{\Phi}_t^{stay}}{\int(1-\eta_{j,t}^s(a,z))d\tilde{\Phi}_t^{stay}} + b_t^H \tag{A.30}$$

9. Law of motion of Φ_t^{stay}:

For any subset $C = C_{\mathcal{J}} \times C_{\mathcal{S}} \times C_{\mathcal{A}} \times C_{\mathcal{Z}} \times C_{\Lambda} \subseteq \{2, ..., J\} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z} \times \Lambda$,

$$\Phi_{t+1}^{stay}(C) = \frac{1}{1+n_{1,t+1}^{H}} \int (1 - m_t(j,s,a,z,\lambda))\psi_j^{Hs} P_t^{stay}\left((j,s,a,z,\lambda), C\right) d\Phi_t^{stay} \quad \text{(A.31)}$$

where

$$P_t^{stay}\left((j,s,a,z,\lambda), C\right) = \begin{cases} \pi^{Hs}(z'|z) \int_{C_\Lambda} f(\lambda) d\lambda & \text{if } j+1 \in C_{\mathcal{J}}, s \in C_{\mathcal{S}}, \\ & a_t'^{stay}(j,a,s,z) \in C_{\mathcal{A}}, z' \in C_{\mathcal{Z}} \\ 0 & \text{otherwise} \end{cases} \quad \text{(A.32)}$$

Hereby, f denotes the probability distribution function of λ.

For any $C = C_{\mathcal{J}} \times C_{\mathcal{S}} \times C_{\mathcal{A}} \times C_{\mathcal{Z}} \times C_{\Lambda} \subseteq \{1\} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z} \times \Lambda$,

$$\Phi_{t+1}^{stay}(C) = \begin{cases} \sum_{s \in C_{\mathcal{S}}} \sum_{z \in C_{\mathcal{Z}}} \nu_1^{Hsz} \int_{C_\Lambda} f(\lambda) d\lambda & \text{if } 0 \in C_{\mathcal{A}} \\ 0 & \text{otherwise} \end{cases} \quad \text{(A.33)}$$

where ν_1^{Hsz} is the share of workers with skill level s and labour productivity z in the cohort of newborn agents in country H.

10. Law of motion of Φ_t^{migr}:

For any subset $C = C_{\mathcal{J}} \times C_{\mathcal{S}} \times C_{\mathcal{A}} \times C_{\mathcal{Z}} \subseteq \{2, ..., J\} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z}$,

$$\begin{aligned} \Phi_{t+1}^{migr}(C) = \frac{1}{1+n_{1,t+1}^{H}} \Bigg[\int \psi_j^{Fs} P_t^{migr}\left((j,s,a,z), C\right) d\Phi_t^{migr} + \\ + \int \eta_{j,t}^{s}(a,z) \psi_j^{Fs} Q_t^{migr}\left((j,s,a,z), C\right) d\tilde{\Phi}_t^{stay} \Bigg] \end{aligned} \quad \text{(A.34)}$$

where

$$P_t^{migr}\left((j,s,a,z), C\right) = \begin{cases} \pi^{Fs}(z'|z) & \text{if } (j+1, s, a_t'^{migr}(j,a,s,z), z') \in C \\ 0 & \text{otherwise} \end{cases} \quad \text{(A.35)}$$

and

$$Q_t^{migr}\left((j,s,a,z), C\right) = \begin{cases} \pi^{Fs}(z'|z_{min}^{Fs}) & \text{if } (j+1, s, a_t'^{migr}(j,a,s,z_{min}^{Fs}), z') \in C \\ 0 & \text{otherwise} \end{cases} \quad \text{(A.36)}$$

For any $C = C_{\mathcal{J}} \times C_{\mathcal{S}} \times C_{\mathcal{A}} \times C_{\mathcal{Z}} \subseteq \{1\} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z}$,

$$\Phi_{t+1}^{migr}(C) = 0 \tag{A.37}$$

Definition 3 A stationary equilibrium is a competitive equilibrium in which per capita variables and functions as well as prices are constant.

B Solution algorithm

In order to solve the model I need to discretize the values of individual savings and idiosyncratic productivity. For individual savings I use the log-space grid with 500 elements. To approximate the distribution of the individual productivities, I use six-state Markov chains. For each discrete value of the state space, I calculate the optimal decision to the agents' optimization problems. Since these problems cannot be solved analytically, I use the numerical maximization methods to obtain the decision rules.

Stationary equilibrium

The algorithm used to solve the stationary equilibrium of the model can be summarized in the following steps:

1. Foreign economy
   - 1.1 Calculate labour supplies per capita h^F and l^F using equations A.6.
   - 1.2 Guess the values of capital per capita k^F and bequests b^F.
   - 1.3 Calculate factor prices r, w^{Fh} and w^{Fl} from equations A.3.
   - 1.4 Compute agents' decisions at the last possible age J. Note that in next period all agents die for sure, so in the last period of life, they consume all their resources. Use backward induction to solve decision problems of younger agents.
   - 1.5 Use computed decision rules to calculate new values of k^F using equation A.5, and b^F using equation A.4, and compare them with the initial guesses. If they are not sufficiently close to each other, update your guess and repeat the algorithm from step 1.3 on.
2. Home economy
   - 2.1 Guess labour supplies per capita h^H and l^H, growth rate of the first generation n_1^H and bequests b^H.
   - 2.2 Use interest rate r determined in the foreign economy to calculate capital per capita k^H using equation A.18.
   - 2.3 Calculate wages w^{Hh} and w^{Hl} from equations A.19.
   - 2.4 Compute agents' decisions at the last possible age J. Note that in next period all agents die for sure, so in the last period of life, they consume all their resources. Use backward induction to solve decision problems of younger agents.

2.5 Use computed decision rules to calculate new values of h^H and l^H using equations A.25, n_1^H using equation A.21 and b^H using equation A.20, and compare them with the initial guesses. If they are not sufficiently close to each other, update your guess and repeat the algorithm from step 2.2 on.

Transiton path

Let $t \in \{0, 1, ...\}$ denote time along transition, with $t = 0$ representing the initial non-migration stationary equilibrium, i.e. equilibrium in which emigration probabilities $\eta_j(a, z)$ are not determined endogenously by A.24 but they are exogenously set to zero. Let $t = 1$ represent the period of opening the borders.

The transition path is computed using the following algorithm:

1. Use algorithm presented above to calculate the stationary equilibria before and after opening the borders. Note that the solution for the foreign economy has to be calculated only once as the country is unaffected by the considered policy change. Hence, no variable from foreign economy varies during transition.

2. Note that the growth rate of the first generation in period t $n_{1,t}^H$ is determined by the population structure from period $t-1$, see equation A.21. Hence, in period $t = 1$ it is the same as in the initial stationary equilibrium, i.e. $n_{1,1}^H = n_{1,0}^H$.

3. Assume that the economy moves from the non-migration to migration stationary equilibrium in the arbitrary, big enough, number of periods $\mathcal{T}$. In other words, assume that in period $t = \mathcal{T}$ the economy is in the migration stationary equilibrium.

4. Guess the path of labour supplies per capita $\{h_t^H\}_{t=1}^{\mathcal{T}-1}$ and $\{l_t^H\}_{t=1}^{\mathcal{T}-1}$ and bequests $\{b_t^H\}_{t=1}^{\mathcal{T}-1}$.

5. Use those paths and the world interest rate r to calculate the sequence of capital stock per capita $\{k_t^H\}_{t=1}^{\mathcal{T}-1}$ from equation A.18.

6. Calculate the sequence of wages $\{w_t^{Hh}\}_{t=1}^{\mathcal{T}-1}$ and $\{w_t^{Hl}\}_{t=1}^{\mathcal{T}-1}$ using equations A.19.

7. Starting from $t = \mathcal{T}$, use backward induction to compute the sequence of agents' optimal decision rules, taking as given the path of prices calculated in the previous step.

8. Starting from $t = 1$, for each period use agents' decision rules to calculate new values of labour supplies h_t^H and l_t^H (equations A.25), and bequests b_t^H (equation A.20), and next period growth rate of the first generation $n_{1,t+1}^H$ (equation A.21).

9. Compare the new sequence $\{h_t^H\}_{t=1}^{\mathcal{T}-1}$, $\{l_t^H\}_{t=1}^{\mathcal{T}-1}$ and $\{b_t^H\}_{t=1}^{\mathcal{T}-1}$ computed in the previous step with the initial guesses. If they are not sufficiently close to each other, update your guess and repeat from step 5 on.

10. Check whether in period $t = \mathcal{T} - 1$ the economy is sufficiently similar to the economy in period $t = \mathcal{T}$. If not, increase $\mathcal{T}$ and repeat from step 4 on.

C Remittances scenario

Outward population movements are usually accompanied by increasing inflow of remittances. These transfers from abroad may affect both the well-being of those staying behind and the macroeconomic aggregates of remittance-receiving countries (see, e.g. Rapoport and Docquier, 2005; OECD, 2007; di Giovanni et al., 2015). Taking into account their potentially important role, in this robustness exercise I augment my model with remittances. In this scenario, I recalibrate the migration costs to ensure that the size and skill structure of emigration in the stationary equilibrium are the same as in the baseline migration steady state. To this end, I set μ_h equal to 0.855 and μ_l equal to 1.192.

In this scenario, the budget constraint of the emigrant from country H given in the baseline model by equation 16 takes the following form:

$$c + a' = (1 + r_t)(a + b_t^H) + (1 - \kappa)w_t^F e_j^F z \tag{C.1}$$

with κ being the fraction of labour income sent to the home country.

To calibrate κ, I use the survey data on emigrants from Poland collected by Polish central bank (NBP). I use data from 2018, which is the last vintage available. In that year, the survey was carried out in four countries on a sample of 1500 individuals in Great Britain, 1500 in Germany, 1000 in Norway and 700 in the Netherlands. The interviews were conducted among Polish citizens aged between 18 and 65 who had left Poland for work purposes. More detailed information on the survey and its methodology can be found in, e.g. Chmielewska (2015) or Chmielewska et al. (2019).

First, I took a look at the questions about the net monthly wage and the amount of money transferred to Poland in the last 12 months. Since in this type of questions, respondents usually prefer not to mention exact numbers, they were also asked to choose one of the provided wage/transfer ranges. If the respondent chose to pinpoint only the wage/transfer range, I assigned him the middle point in the given category. The respondents choosing the last, open-ended wage/transfer category were assigned the value of average wage/transfer calculated for the interviewees belonging to the respective wage/transfer category who also provided the exact answer. Since no emigrant residing in Norway and pointing the last open-ended income range provided the exact value for his wage, it was impossible to evaluate the income of the highest labour income earners in this emigration country. Hence, finally I decided to exclude the respondents from Norway from my analysis. To convert the answers provided by emigrants in Great Britain, Germany and the Netherland into one currency, I used the average exchange rates from 2018.

The ratios of average money transfer remitted to Poland by individuals sending remittances (i.e. declaring transfer greater than zero) to average net annual wage (twelve times the average net monthly wage) calculated for different age and skill groups are provided in Table C.1. The ratio turns out to be pretty constant across the groups and amounts to around 0.2, with a little bit lower value for young skilled agents. Table C.2 presents the fractions of emigrants sending money to Poland. Again, this fraction does not vary significantly across different groups and is equal to around 0.35. Since the numbers of observations in particular age-skill categories are quite small, in my calibration I decided to differentiate the fraction of remitted income only with respect to skills. Multiplying the respective numbers from the last columns of Table C.1 and C.2 gives us the value of κ equal to 0.06 for skilled agents and equal to 0.08 for the unskilled ones.

Table C.1: Average fraction of income remitted to Poland by individuals sending remittances

	18-24 years	25-34 years	35-44 years	45-54 years	55-65 years	All
Skilled	0.11	0.18	0.21	0.18	0.23	0.18
Unskilled	0.22	0.21	0.23	0.26	0.23	0.23

Source: NBP survey data of emigrants from Poland in Great Britain, Germany and the Netherlands, 2018.

Table C.2: Ratio of emigrants sending money to Poland to all emigrants from Poland

	18-24 years	25-34 years	35-44 years	45-54 years	55-65 years	All
Skilled	0.33	0.36	0.37	0.38	0.28	0.36
Unskilled	0.30	0.33	0.38	0.37	0.32	0.35

Source: NBP survey data of emigrants from Poland in Great Britain, Germany and the Netherlands, 2018.

Since the available dataset lacks the information on remittance recipients, I assume that the money sent to the home economy by emigrants is distributed equally among all citizens of the country. Hence, the budget constraint of the agent who decides to stay in the current period in his home country, i.e. equation 20 from the baseline model, is now given by:

$$c + a' = (1 + r_t)(a + b_t^H) + w_t^H e_j^H z + \Xi_t \tag{C.2}$$

with Ξ_t denoting the money transfer received by home country residents from abroad and calculated as follows:

$$\Xi_t = \frac{\int \kappa^s w_t^{Fs} e_j^{Fs} z d\Phi_t^{migr}(\mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z}) + \int \kappa^s w_t^{Fs} e_j^{Fs} z \eta_{j,t}^s(a,z) d\tilde{\Phi}_t^{stay}(\mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z})}{\int (1-\eta_{j,t}^s(a,z)) d\tilde{\Phi}_t^{stay}(\mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{Z})} \tag{C.3}$$

where $\tilde{\Phi}_t^{stay}$ and Φ_t^{migr} denote the measures of agents who were born in country H and reside in the beginning of period t, i.e. before migration decisions are made, in, respectively, country H and country F, expressed relative to the size of the first generation.

Note that in order to solve this version of the model, I need to additionally guess and update in each iteration the value (or the whole path in case of solving the transition path) of money transfer Ξ_t.

Although the long run changes in the economic aggregates in the analysed scenario are roughly similar to the changes observed in the baseline model, see Table C.3, several differences stand out.

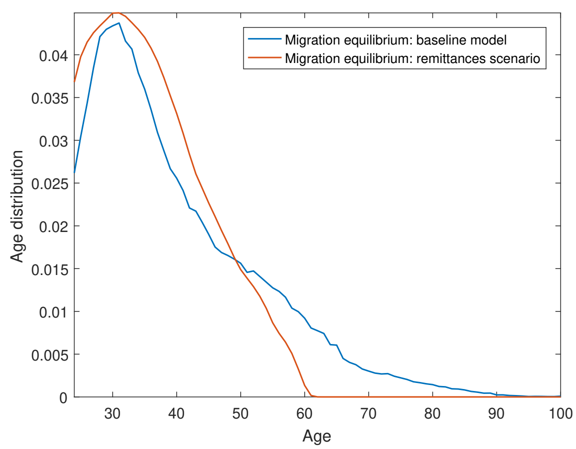
Table C.3: Comparison of stationary equilibria: remittances scenario

	Change
Ratio of emigrants to agents born in the country	16.17 p.p.
Growth rate of the first generation (n_1^H)	-0.60 p.p
Wage per efficiency unit of skilled labour (w^{Hh})	1.02%
Wage per efficiency unit of unskilled labour (w^{Hl})	- 0.39%
Average labour income of skilled worker	3.54%
Average labour income of unskilled worker	0.33%
Capital stock per capita (k_h)	-5.93%
High skill labour per capita (h_H)	-6.59%
Low skill labour per capita (l_H)	-4.93%
Output per capita (y_H)	-5.56%
Capital stock per working age person	0.34%
High skill labour per working age person	-0.40%
Low skill labour per working age person	1.40%
Output per working age person	0.73%
NFA to output ratio	17.39 p.p.
Bequests (b_t^H)	4.08%
Remittances received to GDP ratio	0.98 p.p.

Notes: Table presents changes with respect to the non-migration equilibrium. All measures refer to the home country.

First, even though the size of the emigrant flow is the same in both scenarios, the stock of emigrants is a bit higher in the model with remittances (ratio of emigrants from the home country to all agents born in the country equals 0.162 vs 0.148 in the baseline migration equilibrium). Since in the remittances scenario the incentives to emigrate are lower (as emigrants have to send part of their income to the home country), in order to ensure the desired size of migration flows, the utility costs of migration have to be also calibrated to the level lower than in the baseline model. This modification affects differently the willingness to relocate of various age cohorts and hence impacts the age structure of emigration flows. As can be observed in Figure C.1, the age distribution of emigration flows is now more skewed towards younger generations. Since agents decide to change the country of their residence earlier in their lives, the ratio of emigrants to individuals born in the country in the analysed scenario is higher than in the baseline model.

Figure C.1: Age structure of emigration flows: remittances scenario



Since the emigrant stock in the analysed scenario is higher than in the baseline model, the observed changes in the aggregates are stronger. The only variable which reacts less are the bequests. This is the immediate consequence of the obligation to remit part of the income and hence lower asset accumulation by emigrants.

In the migration equilibrium the sum of money remitted to the home country is equal to 0.98% of its output. This is roughly consistent with the data: according to the World Bank statistics, remittances received by Poles in 2018 constituted around 1.2% of Poland's GDP.

The inequality measures presented in Table C.4 confirm that emigration raises labour income disproportions. The rise in labour income inequalities is, however, a bit weaker than in the baseline scenario. While the difference between wages per efficiency unit of labour received by skilled and unskilled individuals is greater than in the baseline migration equilibrium, the

Table C.4: Inequality measures: remittance scenario

	Non-migration equilibrium	Migration equilibrium
Gini coefficient, labour income	30.59	30.73
Gini coefficient, labour income, skilled workers	29.26	29.04
Gini coefficient, labour income, unskilled workers	28.04	27.94
Theil index, labour income:	14.85	15.03
Within (skill) group inequality	12.51	12.41
Between (skill) group inequality	2.34	2.62
Theil index, labour income, skilled workers	13.23	13.06
Theil index, labour income, unskilled workers	12.23	12.15
Hoover index, labour income	22.91	22.97
20:20 ratio, labour income	4.56	4.60
Gini coefficient, labour income and remittances received	30.59	30.47
Gini coefficient, total disposable income	29.05	28.91
Gini coefficient, assets	54.70	54.99
Hoover index, assets	41.00	41.12

Notes: Measures referring to income are calculated for working age population residing in country H. Measures referring to assets are calculated for total population of the country.

selectivity in terms of individual productivity is more pronounced. This stronger outflow of people from the lower end of individual productivity distribution limits the within-skill-group inequalities and hence mitigates the overall labour income disproportions. Moreover, in this scenario the skill distribution of population living in the home country shifts more towards unskilled agents who are relatively less income-differentiated. This also pushes overall labour income inequalities down. This stronger shift results from the higher than in the baseline migration equilibrium stock of emigrants who are more skilled than the stayers.

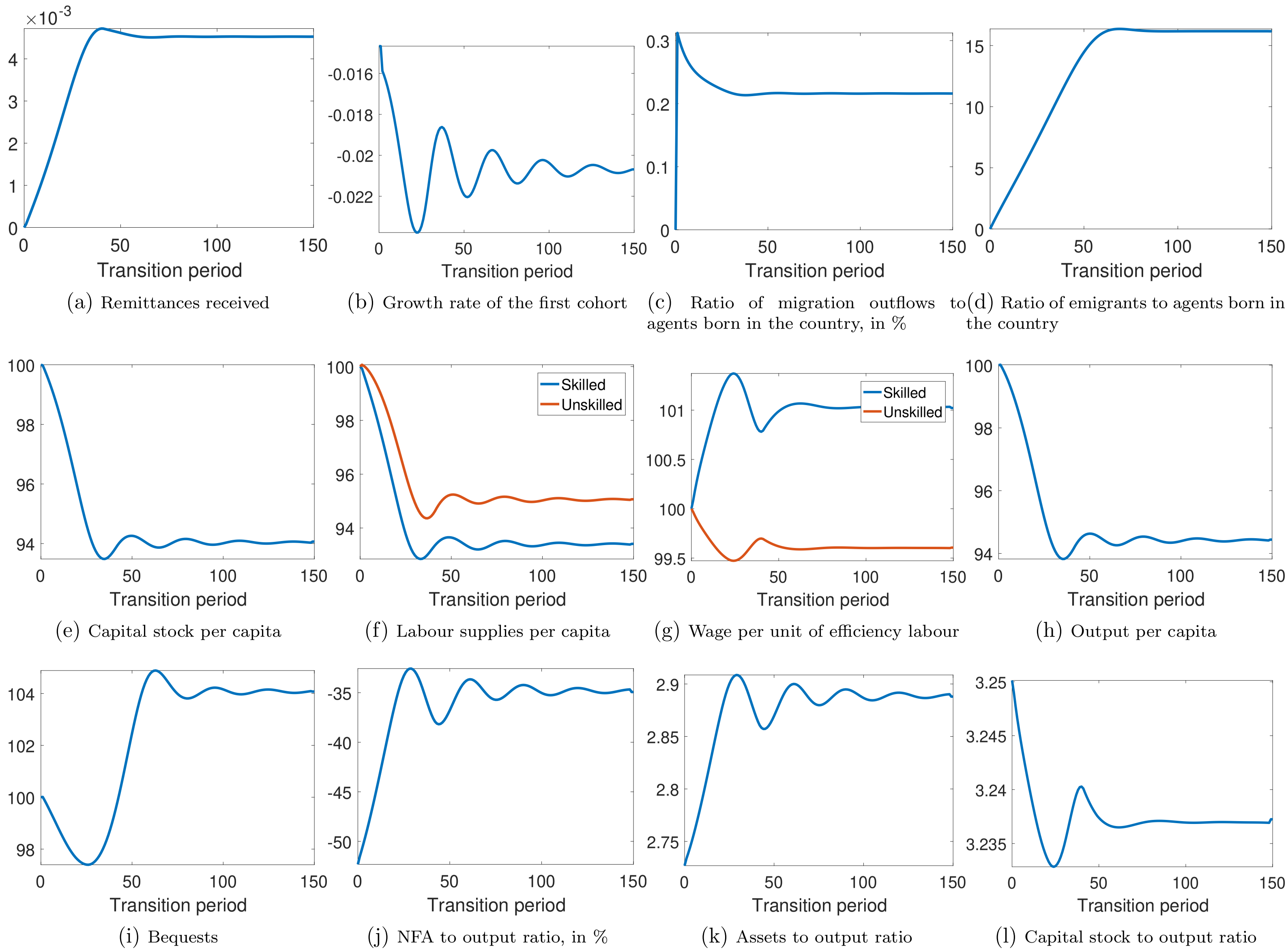
Table C.5: Welfare effects: non-migration equilibrium vs remittance scenario

	Percentage change in lifetime consumption
All	1.64
Skilled	2.40
Unskilled	1.46
Skilled never-migrants	1.97
Unskilled never-migrants	1.11
Bequests fixed at the level from non-migration equilibrium	
All	1.42
Skilled	2.25
Unskilled	1.22
Skilled never-migrants	1.83
Unskilled never-migrants	0.89

Gini coefficients based on incomes including remittances, i.e. labour income and remittances received, and total disposable income which additionally includes bequests and capital income, slightly decline. My analysis shows therefore that money transfers from abroad more than offset rising labour income inequalities in the country of origin. It should be noted that impact of remittances on income inequalities crucially depends on who and how much receives in money transfers from abroad. The empirical analysis conducted by Giannetti et al. (2009), which was based on the EU-SILC data, shows that in Central and Eastern European countries, including Poland, remittances are mainly paid to households from the lower end of the income distribution. Incorporating this finding into my model instead of assuming that remittances are distributed equally among all citizens of the sending country would only strengthen the model conclusions that remittances limit income inequalities.

Table C.5 presents the long run welfare effects of opening the borders in the model with remittances. Obviously, the gains are higher than in the model without money transfers from abroad. Contrary to the baseline model, in this scenario the unskilled never-migrants

Figure C.2: Macro variables along the transition: remittances scenario



(a) Remittances received

(b) Growth rate of the first cohort

(c) Ratio of migration outflows to agents born in the country, in %

(d) Ratio of emigrants to agents born in the country

(e) Capital stock per capita

(f) Labour supplies per capita

(g) Wage per unit of efficiency labour

(h) Output per capita

(i) Bequests

(j) NFA to output ratio, in %

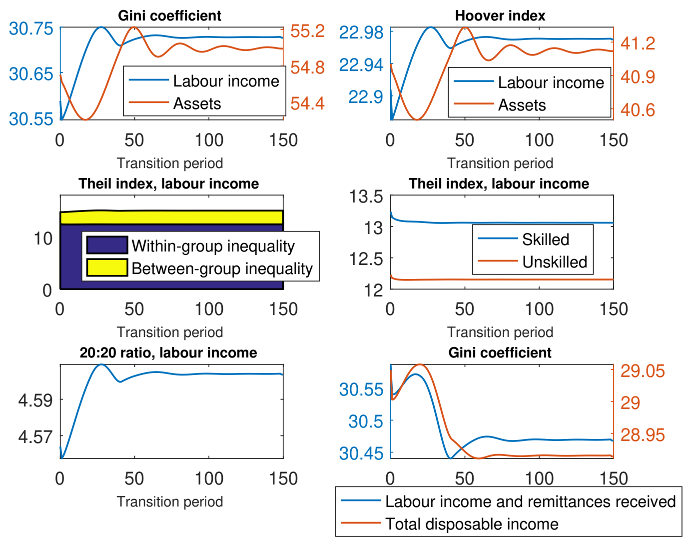
(k) Assets to output ratio

(l) Capital stock to output ratio

Notes: Figures (e)-(i): values in the non-migration equilibrium normalized to 100.

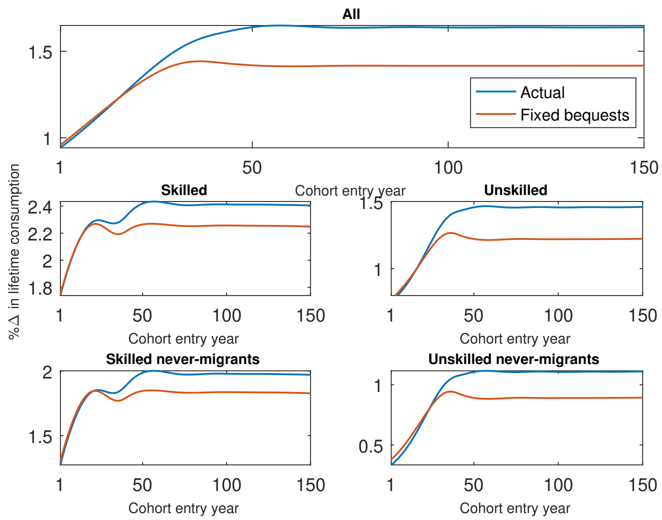
benefit from the open borders even after eliminating the positive role of higher bequests. On average, they would require 0.89% increase of lifetime consumption in the non-migration steady state in order to be indifferent to being born in the new migration equilibrium.
Figures C.2-C.3 present the dynamics of model aggregates and inequality measures along the transition path. As in case of the long run outcomes, the evolution of these variables is not much different than in the baseline model.

Figure C.3: Inequality measures: remittances scenario



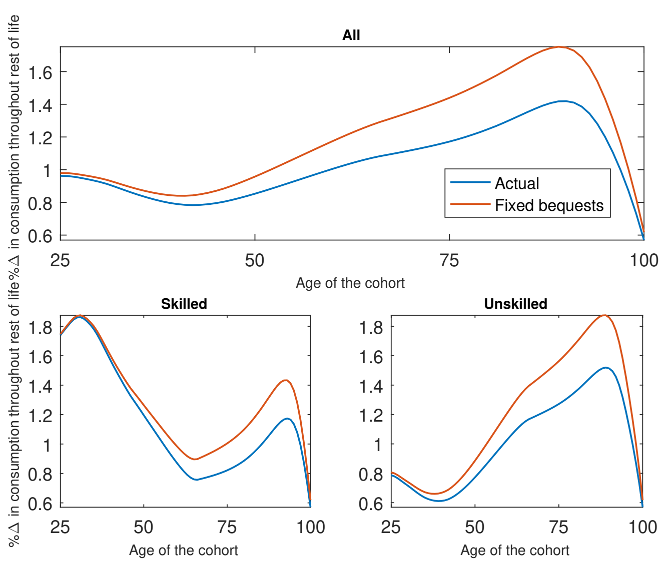
In the analysed scenario, the bequests have much smaller impact on the evolution of welfare measures. As we can see in Figures C.4-C.5, they affect the level of welfare effects, but, contrary to the baseline scenario, does not change the conclusions which age cohorts benefit more and which less from emigration possibility.
As far as the future generations are concerned, the cohorts born late after opening up the borders benefit the most. This holds true for both skill groups and results from the rising remittances received by the individual living in the home country. For the generations born in the periods just after allowing for labour mobility, the actual welfare measures and the welfare measures calculated after eliminating the impact of bequests are more or less the same. These cohorts experience first the decline and then the rise in received bequests (see Figure C.2(i)) and effects of these changes roughly cancel out during their life cycle. The agents born in later periods experience only increases in bequests and hence the actual welfare measure are higher than the measures calculated with fixed bequests.
Looking at the situation of skilled current generations let us notice that the agents who are young at the moment of removing migration barriers gain the most. These agents have

Figure C.4: Welfare effects, future generations: remittances scenario



Notes: Fixed bequests - bequests along the transition are fixed at the level from non-migration equilibrium.

Figure C.5: Welfare effects, current generations: remittances scenario



Notes: Fixed bequests - bequests along the transition are fixed at the level from non-migration equilibrium.

relatively big chances to emigrate to the richer country. Moreover, even if they do not decide to relocate, they enjoy higher wages in the home country and receive transfers from abroad. The gains of the elder workers are lower and then they again increase for the retirees. The individuals after retirement have no incentives to change the country of their residence, but since their consumption is relatively low, even small rise in disposable income due to received remittances leads to high percentage change in consumption. For the unskilled pensioners, this percentage change in consumption is even higher. The welfare effects for unskilled agents who are young when the borders open are relatively low due to falling wage per unit of efficiency labour in the home country.

To sum up, accounting for remittances does not change the general conclusions about the impact of emigration on macroeconomic aggregates. More interestingly, it turns out that money transfers from abroad more than offset the effects of rising wage differential and lead to lower inequalities in disposable income. In the presence of remittances, the welfare gains are higher and, contrary to the baseline scenario, even the unskilled never-migrants benefit from open borders.